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Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2022 19(1): 658-664. **OPEN ACCESS**

Assessment of drought resistance indicators of potato cultivars during drought stress in Tarom, Zanjan

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Iranians use potatoes as the fourth most common food item, making them an important source for ensuring the country's long-term food supply security. Owing to its shallow root structure, this plant is vulnerable to drought. Because of this, an investigation was carried out in 2020-21 in the Tarom district of Zanjan, Iran, using a split-plot of the RDBD in three replications to assess the tolerance indicators. The major variable, namely a dehydration stress intervention at two levels (regular and stressed) and four-level genotypes, have been evaluated as sub-factors. A one-percent probability level analysis of variance in tuber production demonstrated a substantial bilateral influence of water stress on genotype in contexts of year, water stress, and the examined hybrids. No significant differences were seen in other areas of bilateral and trilateral impacts. Under stress, tuber performance in the tested genotypes decreased by 11.18 percent compared to data obtained under normal circumstances. An evaluation of the average bilateral effect of water stress on genotype revealed that the standard combination in hybrid 90227 exhibited the largest tuber productivity and belonged to the better statistical grade, with a mean of 48.22 t / ha. During this research, hybrid 90227 had the maximum average tuber productivity of 48.22 t/ha, whereas cultivar 87031 had the minimum average tuber productivity of 29.4 t/ha under standard circumstances. Hybrid 90227 had the largest tuber production with a mean of 42.42 t / ha during drought stress circumstances, while Kaiser had the lowest with an average of 25.08 t / ha. Hybrid 27515 had the greatest stress tolerance in terms of both the SSI and TOL parameters, as determined by the findings of the tolerance and susceptibility examinations. In addition, 27515 hybrids was shown to be stress-resistant regarding the MP and GMP parameters, among other things. Drought tolerance was excellent in the hybrids 27515 and 27699 because of their higher STI scores.

Keywords: Potato, Marketable tuber production, Stability, Tolerance and sensitivity indexes

INTRODUCTION

Solanum tubersum L, the official nomenclature for the potato, is one of 900 species of the genus Solanum, which belongs to the Solanaceae family (Mosavi, Ozturk et al. 2018). In terms of global food production and behind wheat, maize, and rice, potatoes are the fourth most significant crop globally (Bi, Dan et al. 2021, Chen, Khayatnezhad et al. 2021, Cheng, Hong et al. 2021). Additionally, it is essential in considerations of dietary significance and protein and energy output per unit region (Choukan, Taherkhani et al. 2006, Fataei, Varamesh et al. 2018). Annual potato output in Iran is 275 million tons, making it the country's second-largest food supplier after wheat (Guo, She et al. 2021, Hou, Li et al. 2021). More than a billion inhabitants throughout the globe rely on potatoes as their primary source of food, with more than 125 nations participating in potato production. Potatoes are grown yearly on around 5.19 million hectares of land in the globe, yielding over 368 million tons of potatoes, according to reports. China is the world's greatest manufacturer, followed by India, Russia, Ukraine, and the United States. Iran is placed 12th to 13th in the world and third in Asia, behind China and India, in manufacturing contexts (Fataei, Varamesh et al. 2013, McGuire 2015, Rajaei, Khalili-Arjaghi et al. 2020).

Several stress tolerance criteria have been developed and employed by (Fernandez 1992) and many studies have analyzed their advantages and shortcomings (Gill 1999). Fernandez (1992), relying on the reaction of genotypes to stressful or non-stressful ecological settings, categorized them into four classes as follows: A. cultivars undertaking well throughout stressful and non-stressful settings; B: cultivars undertaking just well throughout a stress-free situation; C: cultivars undertaking well in stressful settings; and D: cultivars with reduced output in both situations. A selection

criterion for stress is the one that can identify group A from the rest of the classes, according to this statement (Huang, Wang et al. 2021). Tolerance index (TI) is presented as the distinction between productivity during stress (Ys) and non-stress (Yp) and mean production index (MPI) and the sum of two scores of Yp and Ys (Rosielle and Hamblin 1981). Smaller scores of tolerance index imply more tolerant crops against stress. Selection depending on the tolerance index, on the other hand, revealed the presence of high-yield cultivars during stressful situations and low-yield cultivars during non-stress settings, according to the results of the investigation of (Jia, Khayatnezhad et al. 2020). Low scores of the MP index suggest that the genotypes are more susceptible to stressful circumstances. With and without stress, selecting based on the MP index will lead to better effectiveness. Stress Sensitivity Index (SSI) is offered to determine stress-sensitive varieties, which is dependent on the productivity of particular cultivars throughout the stress and non-stress conditions, and also the mean output of overall cultivars under these two contexts. It, similar to the tolerance index, demonstrates cultivar susceptibility to stress at higher levels (Khayatnezhad and Gholamin 2021). Mean geometric productivity (GMP) is a more powerful measure than the MP index to distinguish between groups A and C. Due to the fact that this index is less susceptible to various ranges of Ys and Yp, a new index designated as the Stress Tolerance Index (STI) has been developed on this premise. Cultivars exhibiting high yielding capability in non-stress and stressful environments may be identified by this index (Fernandez 1992). Increased STI and GMP indicators suggest greater endurance of crops against stress. The most suitable indicator is capable of discriminating between group A and the remaining three classes (Fernandez 1992). These indicators were utilized by Hassanpanah and Hoseinzadeh (2007)to estimate the water stress resistance of potato varieties. This model is quite effective in identifying resistant genotypes (Khayatnezhad and Nasehi 2021, Li, Mu et al. 2021, Ma, Ji et al. 2021). It's essential to understand how various cultivars respond to water stress and then select cultivars that can be transferred to future generations of crops that are more resistant to water stress because of the limited amount of water available for cultivation. Thus, this work intended to develop hybrids that are resistant and susceptible to dryness tension.

MATERIALS AND METHODS

In the Zanjan area between 2020-21, a split-plot investigation in the manner of RDBD was carried out three times. The primary parameter, namely dehydration stress intervention at two levels (standard and drought tension) and genotypes at four levels, have been analyzed as sub-factors. Each plot contained two 6 m planting rows with a gap of 75 cm between lines and 25 cm on the lines. The start and end plants in each planting row were used as the boundary to avoid water loss between the stressed and control treatments. Initially, all plots were irrigated as usual. As soon as spring soil moisture circumstances permitted, planting and planting bed preparation, comprising fall plowing and supplemental activities such as perpendicular double-disk and land flattening, were carried out.

Table 1: The evaluated hybrids and the three control genotypes

Row	Parents	Hybrid code
1	Kaiser	-
2	Savalan ♀ × Kaiser ♂	14075
3	Luta♀ × Savalan ♂	90227
4	Savalan ♀ × Kaiser ♂	87031

A 50-cm-deep composite soil specimen was captured and delivered to the laboratory following soil processing. Fertilizer is suggested based on the findings of the soil analysis. Sencor herbicide was used to suppress weeds before germination, and while the weeds were in the 2-4 leaf stage, which was the most effective stage. A 14-stage irrigation process was used to prepare plants for stress and normal phases. The initial two phases were identical. The timeframe and volume of water utilized for stress were half that of regular irrigation in the following phases. Drought tolerance indicators (Fernandez 1992) for the genotypes were also generated to ascertain cultivar resistance to dehydration stress employing results from tuber production.

Table 2: Drought tolerance formula

Formula	Index
STI = [(GYi) × (GYp) / ($\bar{Y}$i)2]	**STI**
MP = (GYi + GYp) / 2	**MP**
GMP = [(GYi) × (GYp)]0.5	**GMP**
SSI = [1 - (GYp) / (GYi)] / SI	**SSI**
TOL = (GYi - GYp)	**TOL**
SI = [1 - ($\bar{Y}$p) / ($\bar{Y}$i)]	**SI**

Ys: Effectiveness of a cultivar during dehydration stress,Yp: Effectiveness of a cultivar during standard settings,**:** Mean output of cultivars during dehydration tension, $\bar{Y}_p$**:** Mean performance of cultivars during standard settings,

The susceptibility and stress tolerance indicators (SSI, STI, TOL, MP, and GMP) specified in Table 2 have been used to assess the drought endurance of the studied potato genotypes (Ma, Khayatnezhad et al. 2021). Regarding data extension and deviation, the Kolmogorov-Smirnov analysis has been applied. A randomized full block design with three replications was used to analyze variance. The LSD test was used to compare the average of the assessed features at a 5% probability threshold. SAS 9.1 and SPSS-22 computer software were employed to do numerical computations. The link between characteristics was studied using linear correlation coefficients.

RESULTS AND DISCUSSION

Analysis of variance of tuber productivity for the examined hybrids indicated (Table 3) that the bilateral impacts of water stress on genotype was substantial at a probability threshold of one percent in contexts of year, water tension, and genotype. Additional bilateral and trilateral impacts were found to have no statistically significant differences. The tuber yield of the genotypes tested under stress was 11.18 percent lower than during standard circumstances.

Table 3: Analysis of variance of potato tuber performance

Mean of Square	DF	(S.O.V)
198.22**	1	**Year**
208.037	4	**Error 1**
214.52**	1	**Water stress**
3.801	1	**Water stress × Year**
12.585	4	**Error 2**
985.028**	3	**Genotype**
6.957	3	**Location × Gen**
114.08**	3	**Gen × Water stress**
5.461	3	**Gen × Year × Water stress**
12.458	24	**Error 3**
12.40	Coefficient of variation (%)	

*, ** Significant at p≤0.05 and 0.01, respectively

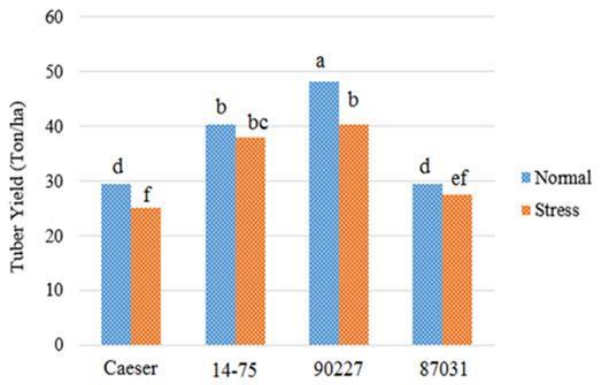

Figure 1: Average bilateral impact of water stress on assessed genotypes

The standard constitution in hybrid 90227, with a mean of 48.22 t / ha, exhibited the largest tuber production and was in the better statistical category when comparing the mean bilateral influence of water tension on genotype (Figure 2). Employing drought tolerance and sensitivity indicators, Naderi Darbagshahi et al. (2004) found that cultivars may be categorized. In addition, it was noted that cultivars were classified as sensitive or tolerant irrespective of their production capability. During standard circumstances and drought tension, tuber output data and the average tuber output of the tested hybrids are displayed in Table 4.

Table 4: Tuber performance and mean tuber yield of hybrids during standard settings and drought stress

No.	Hybrid	Tuber			
		$\bar{Y}_s$	$\bar{Y}_p$	Ys	Yp
1	Kaiser	32.7	36.82	25.08	29.45
2	14-75	32.7	36.82	37.85	40.22
3	90227	32.7	36.82	40.42	48.22
4	87031	32.7	36.82	27.45	29.4

Hybrid 90227 had the greatest tuber production in this research with an average of 48.22 tons/ha, while cultivar 87031 had the lowest with an average of 29.4 tons/ha. Hybrid 90227 had the greatest tuber production with an average of 42.42 t / ha, while Kaiser had the lowest with an average of 25.08 t / ha during drought tension (Table 5). The lower the stress susceptibility index scores, the better the genotype's ability to tolerate stress (Si, Gao et al. 2020, Ren and Khayatnezhad 2021, Sun, Lin et al. 2021). Employing the SSI index, hybrid 27699 and Kaiser cultivar were demonstrated to have the greatest stress tolerance (0.05 and 0.06), respectively, during this investigation. Hybrid 27515 with a TOL index score of 7.8 and Kaiser with a score of 2 were found to have the minimum and maximum tolerance to dehydration stress during this investigation. The hybrid's resistance to stress improved as the MP index enhanced. According to this analysis, hybrid 27515 had the maximum mean yield index of 44.3. It was shown to be more tolerant to drought tension than the hybrids studied. Hybrid 27515, with an index of 44, had the greatest geometric mean productivity among the hybrids evaluated. On the other side, Kaiser had the minimum geometric mean productivity, averaging between 14 and 75. (Table 4). The selection of genotypes featuring higher yield potential under non-stress situations and genotypes exhibiting high yield potential under stressful settings was made easier with the use of the stress tolerance index (STI) (Fernandez 1992). Genotypes with higher scores of the STI and GMP indices are more tolerant to stress than those with lower levels. 27515 and 27699 hybrids exhibited the maximum STI scores during this investigation, demonstrating that these hybrids are tolerant to drought tension (Table 5).

Considering stress and non-stress circumstances, the SSI index provides additional benefits for cultivar selection (Tao, Cui et al. 2021, Wang, Shang et al. 2021). The higher the MP score, the more resistant the genotype is to stress. The stress tolerance index is the best indicator for cultivar identification, according to the findings of numerous studies. A high-yielding cultivar (group A) may be distinguished by this index from two other cultivar groups, each of which has a reasonably higher output only when not stressed (group B) or only when stress is present (group C) (Xu, Ouyang et al. 2021, Yin, Khayatnezhad et al. 2021, Zhang, Khayatnezhad et al. 2021).

Table 5: Average of drought resistance and sensitivity indices in tuber performance of chosen potato hybrids

No.	Name	$\bar{Y}_s$	$\bar{Y}_p$	Ys	Yp	TOL	SSI	MP	GMP	STI
1	75-14	32.7	36.82	25.08	29.45	4.4	0.132	27.3	27.2	0.5
2	27699	32.7	36.82	37.85	40.22	2.4	0.053	39	39	1.1
3	27515	32.7	36.82	40.42	48.22	7.8	0.144	44.3	44	1.4
4	Caeser	32.7	36.82	27.45	29.4	2	0.059	28.4	28	0.6

Table 6: Grade of correlation among drought tolerance indicators and tuber performance in two situations

SSI	GMP	STI	MP	TOL	Ys	Yp	
						1	Yp
					1	0.88	Ys
				1	0.7	0.82	TOL
			1	0.8	0.95**	0.97**	MP
		1	0.93**	0.77	0.95**	0.98**	STI
	1	0.94**	0.92**	0.72	0.97**	0.97**	GMP
1	0.65	0.68	0.67	0.95**	-0.42	0.80	SSI

*, ** Significant at p≤0.05 and 0.01, respectively

The STI and GMP indices of clone 2-397097 were found to have the maximum tuber output during moderate and extreme drought tension, according to Mousavi et al. (2018). As a result, it has been classified as a water-stress-resistant species. To identify cultivars that are more tolerant and sensitive to water scarcity than others, Ziachehreh et al. (2017) employed tolerance index, mean productivity index, stress sensitivity index, geometric mean productivity index, and stress tolerance index. According to Fernandez (1992), the correlation coefficients between the criteria and the output of the cultivar during stressful and desirable circumstances are taken into account when choosing which of the indices is effectively utilized to identify the resistant cultivars among potatoes. The best index is one that has a strong correlation and significance with effectiveness. There should be an important link between the suitable index and effectiveness under both settings, according to Mitra (2001). The MP, STI, and GMP indices all exhibit this characteristic, as seen in Table 6. As a result, the criteria mentioned above may be used to help select potato cultivars that are drought-resistant. TOL and SSI, on the other hand, don't seem to be reliable measures. Stress tolerance indices (STI), mean productivity (MP), and geometric mean productivity (GMP) as favorable indices were shown to be positively and substantially connected with effectiveness during standard and stressful situations in research conducted by Aghili et al. (2012). The STI, MP, and GMP indices have been shown to be the best indicators of drought resilience in investigations on different crops (Fataei, Monavari et al. 2010, Nasehi and Fataei 2012, Varamesh, Hosseini et al. 2014, Hemmati, Fataei et al. 2019, Mohammadi and Fataei 2019, Arjaghi, Alasl et al. 2021). Tubers' efficiency during both standard and dehydration stress settings indicates that STI, MP, and GMP parameters are the best markers of tolerance and susceptibility to dehydration stress, respectively.

CONCLUSION

It was discovered that, in consideration of stress tolerance indicators (SSI and TOL), hybrid 27515 had the maximum stress tolerance compared to all other ones. In addition, the 27515 hybrids were shown to be resistant to stress regarding the MP and GMP parameters. The hybrids 27515 and 27699 were found to exhibit the maximum STI scores, suggesting that they have a high resistance to drought tension.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEDGEMENT

This paper was from my own master thesis.

AUTHOR CONTRIBUTIONS

Masoud Radmanesh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

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