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# Evaluation of Grain Yield and Drought Tolerance Indices in Armenian and Iranian Wheat Varieties Under Irrigated and Non-Irrigated Conditions

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## ABSTRACT

Drought is one of the main abiotic stresses that depends on soil type and rainfall patterns on agrarian land. However, it is mainly responsible for major yield losses in crops. Climate change further compounds the challenges to advanced crop yields. Failure stress reduces crop yield. This research was conducted on grain yield in fifteen Armenian and Iranian wheat varieties to evaluate grain yield and drought tolerance indices. The study was performed with three replications under normal and drought-stress conditions for two years. According to grain yield, eight drought tolerance indices are estimated, including stress tolerance (STI), tolerance index (TOL), stress susceptibility index (SSI), mean productivity (MP), harmonic mean (HM), geometric mean (GMP), yield index (YI), and drought index (DI) for all varieties. The combination of yield analysis, eight drought tolerance indices, and correlation revealed that Navid, Voskehask, Sabalan, and Zare varieties were desirable for drought tolerance. Other varieties were identified as semi-tolerant and sensitive to drought stress.

## Introduction

Wheat ranks second after rice in terms of dietary intake volume, with 68 % of the wheat produced used for food, approximately 19 % for feed, and the rest for other purposes, including industrial biofuels. Wheat imports from developing countries, including the tropics where wheat is not grown, are increasing. Droughts cause reduced crop and pasture yields, crop failures, and scarcity of water supplies, even with advanced technologies and management in recent years (www.climatedata.ca; Qian, et al., 2018). Grain yield is the basis for drought tolerance selection. However, grain yield is affected by many factors aside from drought (Khadka, et al., 2020). Measuring yield by the attribution of physio-morphological traits independent of grain yield improves selection effectiveness by reducing reliance on final grain yield. Stable yield performance of varieties under both normal and failure stress conditions is vital for factory breeders to identify failure-tolerant varieties (Pierivatolum, et al., 2010). Multiple indicators have been proposed to evaluate failure-resistant characteristics in colorful crops based on fine connections between stressed-out and unstressed-out conditions. These indicators include the stress vulnerability indicator (SSI) (Fischer and Maurer, 1978); relative failure indicator (RDI) (Fischer and Wood, 1979); mean productivity (MP) (Rosielle and Hamblin, 1981), stress forbearance indicator (STI) and geometric mean productivity (GMP) (Fernandez, 1992). More recently, indicators of failure forbearance have included the abiotic forbearance indicator (ATI), stress vulnerability chance indicator (SSPI), and a relative drop in yield (RDY) (Farshadfar and Elyasi, 2012). The present study compares and estimates different yield-grounded failure-forbearance selection indicators for Armenian and Iranian wheat varieties.

## Materials and methods

A pot experiment was conducted to determine the effects of water stress on grain yield. The experimental material consisted of fifteen Armenian and Iranian wheat varieties (Sardari, Navid, Alvand, Mihan, Azar2, Sabalan, Zare, Pishgam, D92, G31, Sateni22, Akhtamar, Armianka60, Voskehask, and Nairi68). Wheat varieties were collected from the East - Azerbaijan Agricultural and Natural Resources Research and Education Centre and the Department of the Scientific Center for Agronomy and Plant Protection of the Republic of Armenia.

The study was conducted at the "Arman Naghsh-Sabz Aras Co." greenhouse site of Ara's free zone in Iran during the 2018–19 and 2019–20 growing seasons (October to July). Jolfa is located northwest of East Azerbaijan Province. In terms of longitude, it lies between 45°17' and 46°31', and in terms of northern latitude, it lies between 38°39' and 39°2'. It is a narrow strip on the province's northern border. AFZ is located in Iran's semi-dry and semi-cold North-West. Annual rainfall is about 225 to 400 milliliters per year, and the average temperature is about 15 degrees Celsius. About 50 days per year are cold. The AFZ is near high mountain ranges, with a chilly climate (www.en.wikipedia.org).

Three replications in two years were conducted with six seeds in every pot. Grain yield was measured at physiological maturity per pot. Eight drought indices including SSI, STI, TOL, GMP, MP, HM, YI, and DI were calculated based on grain yield under normal and drought stress conditions according to the following equations:

stress susceptibility index = SSI= (1-(Ys/Yp))/SI
(Fernandez, 1992).

Stress tolerance index = STI= (Yp*Ys)/ Ȳp2
(Fernandez, 1992).

Tolerance = TOL=Yp-Ys
(Hossain, et al., 1990).

Geometric mean productivity= GMP = $\sqrt{\left(Y_p * Y_S\right)}$
(Fernandez, 1992).

Mean Productivity =MP=(Yp+Ys)/2
(Rosielle and Hambline, 1981).

Harmonic Mean = HM=2*(Yp*Ys)/(Yp+Ys)
(Chakherchaman, et al., 2009).

Yield index = YI = Ys/ Ȳs
(Chakherchaman, et al., 2009).

Drought resistance index = DI = Ys x(Ys/Yp)/ Ȳs
(Lan, 1998),

where Yp is the yield under non-stress conditions, Ys is the yield under stress conditions; Ȳp is the mean yield of all verities; Ȳs is the mean yield of all varieties; and SI = 1-(Ȳs/Ȳp) (Khosravi, et al, 2020). After calculating different indices, the correlation between grain yield under normal and stress conditions (Yp, Ys) and stress tolerance indices was calculated and the best index was determined. So, indices with a significant correlation with grain yield under both conditions were introduced as the most reliable indicators.

## Results and discussions

A total of eight indices of drought tolerance were calculated for each variety (Figure 1 and Table 1). The use of these indices is considered most suitable for selecting drought-tolerant varieties by many researchers. The grain yields of non-irrigated and irrigated fields were significantly different. Grain yield decreased by 50 % when not irrigated. The stress intensity index (SI) ranges from 0 to 1. More significant values of stress intensity indicate more severe stress conditions (Raman, et al., 2012). The SI value in this study was 0.45. Drought-tolerant varieties have high values of GMP, MP, HM, and DI and small values of SSI and TOL (Gitore, et al., 2021). Navid, Voskehask, Sabalan, and Zare are classified as tolerated varieties according to the TOL index. In the case of the yield index, tolerance is defined as a value that is greater than one. In contrast, susceptibility is defined as a verity with a value less than one. SSI and YI indicate that Navid, Voskehask, Sabalan, and Zare are drought-tolerant as are Azar2, Sateni22, and Akhtamar. Under stress conditions, verities with high-value MP, GMP, and HM indices are more admirable

(Gitore, et al., 2021). Varieties Navid, Voskehask, Sabalan, Zare, and Azar2 were detected as tolerant based on these three indices. Gitore et al. (2021) define tolerance as a verity greater than one, while susceptibility as a verity less than one. DI is another index of drought resistance, which was commonly accepted to identify varieties producing high yield under both stress and no-stress conditions by Lan (1998). In this study, the DI index selected only Navid and Voskehask varieties as drought tolerant.

STI-high varieties usually have a significant difference in yield under two different humidity conditions (Lan, 1998). The DI and STI consider not only the ability of varieties to grow well under stressed environments but also superior performance in non-stressed environments (Bahrami, et al., 2020; Sabaghnia and Janmohammadi, 2014). High STI values indicate tolerance to moisture stress in Navid, Voskehask, and Sabalan. Low values indicate low tolerance to moisture stress, such as Mihan, G32, and D31.

Other researchers have also used different indices for selecting resistant varieties of various crops. For instance, STI and GMP in maize (Khallili, et al., 2004), and safflower (Majidi, et al., 2011; Bahrami, et al., 2014). According to grain yield and drought indices, varieties Navid, Voskehask, Sabalan, and Zare were detected as drought tolerant. Azar2, Sateni22, and Akhtamar were classified as those that were not too tolerant but showed a high grain yield value. On the other hand, Alvand, Pishgam, following Sardari, Nairi68, and Armianka60 were identified as semi-sensitive varieties, and Mihan, G32, and D92 were listed as sensitive to drought stress. In our previous study, we used reverse transcription PCR to evaluate the relative water content (RWC) and expression level of Wdhn13 and WCS120 DHN genes. According to the results, the Navid, Sabala, Zare, and Voskehask varieties were highly resistant. In the second place were Azar 2, Sateni 22, and Akhtamar. Sardari, Alvand, Pishgam, Nairi 68, and Armyanka 60 were in the third place. Mihan, D92, and G31 were evaluated as sensitive varieties because the expression of their genes began when the percentage of water content decreased (Vahramians and Melikyan, 2022).

Various strategies for improving plant yield in stressful environments have been proposed to increase plant breeding efficiency. Given the fact that successful breeding programs can be measured against a range of indices, an ideal tolerance index should have high discriminative power to identify superior varieties with long-term yield stability (Mevlut and Sait, 2011).

As shown in Table 2, grain yield under irrigated and non-irrigated conditions is correlated with drought-tolerant indices. The correlation between YP and YS was strong and significant for all indices. A strong correlation of grain yield with other indices for selecting tolerant varieties is essential (Farshadfar, et al., 2012). The correlation between grain yield, SSI, and TOL was negative, and significant under two conditions. These results agree with those reported by (Anwar, et al., 2020; Khosravi, et al., 2020) in wheat.

The drought-tolerant indices showed a strong positive correlation under both non-stress and stress conditions, indicating that these indices were comparably effective for selecting and predicting better grain-yielding varieties under both moisture regimes, corroborating previous reports (Sardouie-Nasab, et al., 2015; Darzi-Ramandi, et al., 2016).

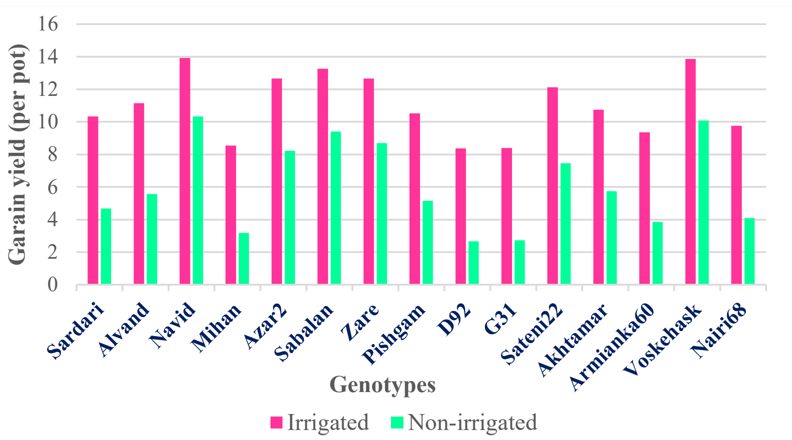


**Figure 1.** Grain Yield of 15 wheat verities under irrigated and non-irrigated conditions *(composed by the author)*.

**Table 1.** Yield potential (YP), stress yield (YS), and eight indices of drought tolerance for 15 wheat verities*

| | TOL | SSI | STI | MP | GMP | HM | YI | DI |
|---|---|---|---|---|---|---|---|---|
| Sardari | 5.66 | 1.22 | 0.45 | 7.51 | 6.96 | 6.44 | 0.76 | 0.35 |
| Alvand | 5.58 | 1.11 | 0.58 | 8.35 | 7.87 | 7.42 | 0.91 | 0.45 |
| Navid | 3.58 | 0.57 | 1.35 | 12.13 | 12.00 | 11.87 | 1.69 | 1.26 |
| Mihan | 5.36 | 1.39 | 0.26 | 5.87 | 5.22 | 4.65 | 0.52 | 0.19 |
| Azar2 | 4.43 | 0.78 | 0.97 | 10.44 | 10.20 | 9.96 | 1.34 | 0.87 |
| Sabalan | 3.85 | 0.65 | 1.17 | 11.34 | 11.17 | 11.01 | 1.54 | 1.09 |
| Zare | 3.96 | 0.70 | 1.03 | 10.67 | 10.48 | 10.30 | 1.42 | 0.98 |
| Pishgam | 5.36 | 1.13 | 0.51 | 7.83 | 7.36 | 6.91 | 0.84 | 0.41 |
| D92 | 5.70 | 1.52 | 0.21 | 5.51 | 4.72 | 4.04 | 0.43 | 0.14 |
| G31 | 5.67 | 1.50 | 0.21 | 5.57 | 4.79 | 4.12 | 0.45 | 0.14 |
| Sateni22 | 4.68 | 0.86 | 0.85 | 9.79 | 9.51 | 9.23 | 1.22 | 0.75 |
| Akhtamar | 4.99 | 1.03 | 0.58 | 8.24 | 7.85 | 7.48 | 0.94 | 0.50 |
| Armianka60 | 5.52 | 1.31 | 0.34 | 6.60 | 6.00 | 5.45 | 0.63 | 0.26 |
| Voskehask | 3.79 | 0.61 | 1.31 | 11.97 | 11.81 | 11.66 | 1.65 | 1.20 |
| Nairi68 | 5.69 | 1.29 | 0.37 | 6.93 | 6.31 | 5.76 | 0.67 | 0.28 |

*Composed by the author.

TOL and SSI showed a significantly negative correlation with all selection indices, which agrees with the observations. STI and GMP indices were the more objective criteria used to select heat-tolerant and high-yielding varieties. These correlations indicate that higher MP and GMP varieties are superior under stress conditions. These results agree with those reported by some scientists (Khosravi, et al., 2020).

There was a significant positive correlation between STI, MP, GMP, HM YI, and DI. Since GMP is calculated based on MP, so high MP values distinguish high-yielding drought-tolerant wheat varieties (Anwar, et al., 2020). The TOL index correlated negatively with all traits except the SSI, which showed a positive correlation. The results were consistent with those reported by Golabadi, et al., (2006) in durum wheat and Khalili, et al., (2012) in canola.

**Table 2.** Correlation coefficients between drought tolerance indices and seed yield in normal conditions*

| | *TOL* | *SSI* | *STI* | *MP* | *GMP* | *HM* | *YI* | *DI* |
|---|---|---|---|---|---|---|---|---|
| TOL | 1 | | | | | | | |
| SSI | 0.94 | 1 | | | | | | |
| STI | -0.96 | -0.99 | 1 | | | | | |
| MP | -0.94 | -0.99 | 0.97 | 1 | | | | |
| GMP | -0.94 | -0.98 | 0.97 | 0.99 | 1 | | | |
| HM | -0.94 | -0.98 | 0.97 | 0.99 | 0.99 | 1 | | |
| YI | -0.95 | -0.99 | 0.97 | 0.99 | 0.99 | 0.99 | 1 | |
| DI | -0.97 | -0.98 | 0.97 | 0.97 | 0.99 | 0.97 | 0.97 | 1 |

*(Yp) grain yield under irrigated conditions; (Ys) grain yield under non-irrigated conditions; (SSI) Stress susceptibility index; (STI) Stress tolerance index; (TOL) tolerance; (MP) mean productivity; (GMP)Geometric mean productivity; (HM) Harmonic mean; (YI) Yield index; (DI) Drought resistance index*

*Composed by the author.

**Conclusion**

Among the varieties identified, Navid, Voskehask, Sabalan, and Zare were recognized as drought-resistant and high-yielding varieties. Regardless of whether they are irrigated or not, they can perform well. This potential can be used in future breeding programs or genetic engineering programs for drought-stress abilities. Also, the results of an evaluation of the effect of failure stress on grain yield using stress forbearance indices suggested that breeders should choose the indices based on stress inflexibility in the target terrain.

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