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# Evaluation of drought tolerance indices in bread wheat recombinant inbred lines

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**ABSTRACT**

*Drought stress is the most important factor to limiting access to high yield which this occurred by restricting growth in most stages of crop growth in arid and semiarid areas. In order to determine the best index and also identifying the best drought-resistant of bread wheat recombinant inbred lines (RILs), 79 RILs derived from a cross between a commercial variety Yecoro Rojo and NO.49 an Iranian local genotype were assessed using square lattice design under normal and water deficit conditions. Results of variance analysis of yield in two conditions showed that there was significant difference between under study genotypes for grain yield in non-stressed and normal conditions. Line 86 produced the highest grain yield in normal conditions (351.22 kg/ $m^2$), while in drought conditions, the highest grain yield (212.295 kg/$m^2$) from line 37. Different drought tolerance indices include Stress Tolerance (Tol), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI) and Stress Tolerance Index (STI), were evaluate based on grain yieldunder rain-fed (Ys) and normal irrigation (Yp) environments. MP, GMP, STI and had the highest correlation with yield in both conditions, selected as the best indices. Considering these three factors Lines 52, 65 and 86 were identified as the most tolerant to drought.*

**Key words:** Drought Tolerance Indices, Grain yield, Wheat.

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## INTRODUCTION

Wheat (*Triticum aestivum* L.), the world's most important and widely adapted crop in terms of area and production and contributes more calories and protein to the world's diet than any other food crop [1]. Drought stress, which is the most serious environmental problem limiting crop production in rainfed agriculture [2], can severely impact plant growth and development, limit plant production and the crop performance [3]. Although wheat is a relatively drought tolerant species but, Under rainfed growing conditions, seasonal fluctuations in water availability may severely affect grain yield during water deficient periods. The most suitable cultivar for such environments would produce high yields when rainfall is abundant and without major yield reduction under rainfall shortages [4].

To evaluate response of plant genotypes to drought stress, some selection indices has been proposed based on a mathematical relation between stress and optimum conditions [5]. Drought indices, describing the relations between yield under stress and yield under favorable conditions have been widely used [6]. These indices are either based on drought resistance or susceptibility of genotypes [7].

Fernandez [7] had divided genotypes reaction on the basis of their yields into 4 categories under stressed and non-stressed conditions: group A are genotypes which have high yield in both of conditions; group B are genotypes which have a high yield under non-stressed conditions; group C including genotypes which have a good yield under stressed conditions and finally group D are genotypes which have a low yield in both conditions. D).Therefore, as

Fernandez [7] stated, the best index for stress tolerance selection is one that can be able to separate group A from others.

Rosielle and Hamblin [8] introduced tolerance indices (TOL: tolerance) and the Mean Productivity (MP: mean productivity), while Fisher and Maurer (1978) offered stress susceptibility index (SSI: stress susceptibility index), Fernandez [7] defined a new advanced index (STI = Stress tolerance index). One of the yield based estimates of drought resistance are geometric mean (GM), Geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years. These indices are used in the current study in identify potential tolerant and/or high yielding cultivars suited to drought prone growing conditions.

## MATERIALS AND METHODS

Current research was undertaken in Tabriz university research station (1360m above mean sea level, longitude: 46˚, 1ǵ E and latitude: 38˚, 5́ N). The population studied consisted of 79 F7 recombinant inbred lines (RILs) obtained by single seed descent from a cross between No.49 genotype as maternal parent (Tall, drought-resistant, Iranian origin) to Yecora Rojo cultivar as paternal parent (dwarf, semi-resistant to drought, American origin) and the parents. The assessment carried out in the form of dual square lattice pattern under both normal irrigation and lack of irrigation conditions. Each test unit was comprised of three rows of two-meter length placed at 15cm intervals for each genotype.

Drought tolerance indices were calculated by the following formula (Table I).

**TABLE 1. IDROUGHT TOLERANCE INDICES**

| Index | Formula | Reference |
|---|---|---|
| Stress Tolerance | TOL = Yp – Ys | Rosielle and Hamblin [8] |
| Mean Productivity | MP = (Yp + Ys) / 2 | Rosielle and Hamblin[8] |
| Geometric Mean Productivity | GMP = $(Yp * Ys)^{0.5}$ | Fernandez [7] |
| Stress Susceptibility Index | SSI = [(1 – (Ys / Yp)] / SI | Fischer and Maurer [13] |
| Stress Tolerance Index | STI = (Yp * Ys) / $(\overline{Y_p})^2$ | Fernandez[7] |

Where in these equations Ys and Yp are average yield of all genotypes under stress and optimal conditions, respectively. $\overline{Y_s}$ and $\overline{Y_p}$ are the mean yields over all genotypes evaluated under stress and non-stress conditions. SI is the stress intensity and calculated as: SI=[1-($\overline{Y_s}$)/$\overline{Y_p}$]

## RESULTS AND DISCUSSION

Analysis of variance (ANOVA) grain yield was based on square lattice design under normal and water deficit conditions. Incomplete block was not effective in two environment (normal and drought conditions) for grain yield analysis of variance this trait carry out based on randomized complete blocks design (RCBD) (Table 2). The results showed that there were significant differences among genotypes in respect to grain yield under non-stress conditions ($p < 0.01$). These results demonstrate high diversity among genotypes that enable us to select genotypes under non-stress and stress environments.

Mean comparisons showed that line 86 with 351.222 $g.m^2$ and Lines 14 with 68.264 $g.m^2$, respectively had the highest and the lowest grain yield under non-stress conditions (Yp) (Table III). Under drought condition (Ys) line 37 with 212.295 $g.m^2$ and line 39 with 45.249$g.m^2$, respectively had the highest and the lowest grain yields, too.

Stress sensitive index (SSI) which its numerical is in low amount (less than one) indicated high tolerance of variety to stress [9]. TOL and SSI indices, which indicate in lower amounts relative tolerance to stress, had identified lines 15 and 79 (with yields 0.256 $g/m^2$, and 0.039 $g/m^2$, respectively) as tolerant. Lines 52, 65 and 86 were the tolerant genotypes based on Mean Productivity (MP), Geometric Mean Productivity (GMP) and Stress Tolerance Index (STI which their high quantity is indicating tolerant genotypes (Table 2).

The results showed that, TOL had a positive and significant correlation with SSI in 1% possibility level (table 3). As Rosielle and Hamblin [8] declared in most of the experiments he correlation between these two indices have been positive, and the selection according to SSI index is in profit of the genotypes which have low yield potential in normal condition and high yield in stress condition.

MP index showed a positive and significant correlation in 1% possibility level with GMP, STI, TOL, Ys and Yp. MP index showed a negative correlation with SSI.

mean production, geometric mean production, stress tolerance index indices had a significant correlation with the yield of the genotypes in stress and normal conditions.

Farshadfar et al. [10] believed that the best suitable index to select stress tolerance varieties, is index in which there is relatively high correlation with grain yield in both stressed and non-stressed conditions. Therefore, mean productivity (MP), geometry mean of productivity (GMP) and stress tolerance index (STI) show high correlation in both normal irrigation and drought stress conditions, introduced as major indices. Similar results were reported by Shahryari and Mollasadeghi [11] Nazari L,and Pakniyat [12].

## DISCUSSION

Based on tolerance indices at non-stress and stress conditions, the most tolerant genotypes was lines 52, 65 and 86. The best indices to select barley genotypes were MP, STI and GMP. Thus, they can use to detect genotypes which have low water requirements and/or suffer less yield reduction by water shortage during their growth period, to be advised to cultivate in regions with limited water resources in order to enhance cultivated area and production efficiency.

**Table 1: Estimation of sensitivity rate of 12 wheat genotypes by different drought tolerance indices under normal and stressed conditions**

| Number | Ys | Yp | MP | GMP | TOL | SSI | STI |
|---|---|---|---|---|---|---|---|
| 1 | 117/684 | 159/201 | 138/443 | 136/878 | 41/517 | 2/260 | 0/671 |
| 2 | 87/312 | 188/563 | 137/938 | 128/312 | 101/251 | 4/653 | 0/588 |
| 4 | 95/138 | 187/473 | 141/306 | 133/551 | 92/335 | 3/455 | 0/638 |
| 5 | 105/377 | 175/096 | 140/187 | 135/771 | 69/820 | 1/331 | 0/659 |
| 6 | 174/266 | 205/884 | 190/075 | 189/417 | 31/618 | 2/998 | 1/282 |
| 7 | 80/087 | 122/450 | 101/269 | 99/029 | 42/362 | 2/769 | 0/381 |
| 8 | 164/717 | 242/075 | 203/396 | 199/625 | 77/358 | 2/698 | 1/425 |
| 9 | 180/832 | 262/569 | 221/701 | 217/925 | 81/737 | 4/040 | 1/697 |
| 10 | 134/886 | 252/714 | 193/801 | 184/629 | 117/117 | 4/040 | 1/218 |
| 11 | 82/762 | 103/900 | 93/332 | 92/731 | 21/138 | 1/763 | 0/307 |
| 12 | 108/507 | 236/653 | 172/581 | 160/246 | 128/146 | 4/629 | 0/918 |
| 13 | 148/618 | 169/908 | 159/264 | 158/907 | 21/289 | 1/086 | 0/903 |
| 14 | 53/652 | 68/264 | 60/958 | 60/519 | 14/612 | 1/655 | 0/131 |
| 15 | 56/674 | 56/930 | 56/802 | 56/802 | 0/256 | 0/039 | 0/115 |
| 16 | 82/569 | 92/827 | 87/698 | 87/547 | 10/258 | 0/958 | 0/274 |
| 17 | 129/933 | 194/927 | 162/430 | 159/146 | 64/995 | 2/889 | 0/905 |
| 18 | 101/732 | 170/660 | 136/197 | 131/764 | 68/929 | 3/500 | 0/621 |
| 19 | 150/199 | 159/214 | 154/707 | 154/641 | 9/015 | 0/491 | 0/855 |
| 20 | 89/852 | 148/412 | 119/133 | 115/479 | 58/560 | 3/419 | 0/477 |
| 21 | 177/847 | 267/172 | 222/507 | 217/979 | 89/329 | 2/897 | 1/698 |
| 22 | 122/447 | 141/822 | 132/135 | 131/779 | 19/375 | 1/187 | 0/621 |
| 23 | 86/334 | 124/223 | 105/279 | 103/560 | 37/879 | 2/643 | 0/383 |
| 24 | 197/110 | 254/552 | 225/831 | 223/998 | 57/443 | 1/955 | 1/793 |
| 26 | 111/294 | 204/514 | 157/955 | 150/937 | 93/120 | 3/946 | 0/814 |
| 27 | 109/693 | 214/404 | 162/049 | 153/359 | 104/711 | 4/232 | 0/841 |
| 28 | 66/298 | 130/221 | 98/260 | 92/917 | 63/923 | 4/254 | 0/309 |
| 29 | 190/587 | 192/901 | 191/744 | 191/741 | 2/315 | 0/104 | 1/314 |
| 30 | 104/703 | 251/563 | 178/133 | 162/294 | 146/860 | 5/059 | 0/941 |
| 31 | 120/170 | 198/664 | 159/412 | 154/511 | 78/494 | 3/424 | 0/853 |
| 32 | 71/912 | 145/225 | 108/568 | 102/394 | 73/313 | 4/375 | 0/373 |
| 33 | 128/720 | 167/258 | 147/989 | 146/730 | 38/537 | 1/997 | 0/770 |
| 34 | 161/249 | 167/991 | 164/620 | 164/164 | 6/742 | 0/348 | 0/968 |
| 35 | 130/806 | 234/569 | 182/688 | 175/166 | 103/763 | 3/733 | 1/090 |
| 36 | 150/760 | 175/593 | 163/177 | 162/704 | 24/833 | 1/225 | 0/924 |
| 37 | 212/295 | 233/497 | 222/896 | 222/644 | 21/202 | 0/787 | 1/772 |
| 39 | 45/259 | 76/060 | 60/660 | 58/672 | 30/801 | 3/509 | 0/123 |
| 40 | 165/632 | 231/467 | 198/545 | 195/779 | 65/684 | 2/465 | 1/370 |
| 41 | 82/021 | 85/456 | 83/739 | 83/721 | 3/435 | 0/348 | 0/251 |
| 42 | 114/951 | 209/800 | 162/376 | 155/296 | 94/849 | 3/918 | 0/862 |
| 43 | 83/466 | 86/534 | 85/001 | 84/987 | 3/069 | 0/307 | 0/258 |
| 44 | 104/508 | 124/766 | 114/361 | 113/935 | 19/705 | 1/307 | 0/464 |
| 45 | 196/791 | 244/766 | 220/779 | 219/219 | 47/975 | 1/698 | 1/722 |
| 47 | 96/966 | 140/140 | 118/764 | 116/746 | 43/595 | 2/688 | 0/487 |
| 48 | 161/731 | 184/704 | 173/218 | 172/836 | 22/973 | 1/078 | 1/068 |
| 49 | 119/015 | 148/994 | 134/005 | 133/164 | 29/980 | 1/744 | 0/634 |
| 50 | 81/842 | 138/113 | 109/978 | 106/319 | 56/671 | 3/531 | 0/404 |
| 51 | 108/037 | 117/125 | 112/581 | 112/489 | 9/088 | 0/672 | 0/452 |
| 52 | 202/528 | 320/350 | 261/439 | 254/715 | 117/724 | 3/187 | 2/319 |
| 53 | 143/206 | 171/386 | 156/296 | 156/664 | 28/180 | 1/425 | 0/877 |
| 54 | 74/933 | 145/855 | 110/395 | 104/544 | 70/922 | 4/214 | 0/391 |

**Table 1: Estimation of sensitivity rate of 12 wheat genotypes by different drought tolerance indices under normal and stressed conditions**

| Number | Yp | Ys | MP | GMP | TOL | SSI | STI |
|---|---|---|---|---|---|---|---|
| 55 | 116/807 | 269/978 | 193/393 | 177/583 | 153/153 | 4/916 | 1/127 |
| 57 | 138/283 | 211/225 | 174/754 | 170/906 | 72/942 | 2/992 | 1/044 |
| 58 | 203/858 | 209/857 | 206/808 | 206/787 | 5/899 | 0/244 | 1/528 |
| 59 | 142/045 | 174/884 | 158/465 | 157/612 | 32/840 | 1/627 | 0/888 |
| 61 | 127/754 | 153/622 | 140/889 | 140/093 | 25/886 | 1/459 | 0/702 |
| 62 | 131/253 | 239/604 | 185/279 | 177/228 | 108/51 | 3/913 | 1/123 |
| 63 | 178/870 | 212/547 | 200/209 | 199/828 | 24/677 | 1/006 | 1/427 |
| 64 | 128/065 | 207/914 | 167/990 | 163/177 | 79/849 | 3/328 | 0/952 |
| 65 | 195/774 | 327/687 | 261/731 | 253/284 | 131/913 | 3/488 | 2/293 |
| 66 | 180/041 | 234/226 | 207/234 | 205/355 | 54/184 | 2/005 | 1/507 |
| 67 | 200/852 | 247/348 | 224/101 | 222/982 | 46/496 | 1/629 | 1/776 |
| 68 | 59/039 | 170/911 | 114/976 | 100/452 | 111/872 | 5/672 | 0/361 |
| 69 | 160/782 | 247/947 | 204/365 | 199/663 | 87/411 | 3/046 | 1/425 |
| 70 | 123/832 | 197/013 | 160/423 | 156/194 | 73/181 | 3/319 | 0/872 |
| 71 | 77/928 | 141/345 | 109/637 | 104/925 | 63/417 | 3/888 | 0/394 |
| 72 | 187/007 | 257/776 | 222/397 | 219/563 | 70/780 | 2/379 | 1/723 |
| 73 | 104/776 | 204/844 | 154/811 | 146/146 | 100/068 | 4/233 | 0/767 |
| 74 | 183/564 | 224/224 | 203/891 | 202/875 | 40/453 | 1/571 | 1/471 |
| 75 | 146/756 | 174/592 | 160/674 | 160/160 | 27/836 | 1/382 | 0/916 |
| 76 | 130/284 | 140/140 | 135/299 | 135/135 | 9/630 | 0/596 | 0/645 |
| 78 | 181/960 | 229/893 | 205/927 | 204/528 | 47/933 | 1/806 | 1/495 |
| 79 | 93/782 | 94/702 | 94/242 | 94/241 | 0/920 | 0/084 | 0/317 |
| 80 | 96/496 | 117/193 | 106/845 | 106/343 | 20/696 | 1/530 | 0/404 |
| 81 | 194/562 | 198/923 | 196/743 | 196/731 | 4/362 | 0/190 | 1/383 |
| 82 | 81/156 | 142/192 | 111/674 | 107/423 | 601/036 | 3/720 | 0/412 |
| 83 | 86/477 | 132/088 | 109/283 | 106/877 | 45/611 | 2/999 | 0/408 |
| 84 | 209/749 | 251/511 | 230/630 | 229/683 | 41/762 | 1/139 | 1/886 |
| 86 | 181/090 | 351/222 | 266/156 | 252/196 | 170/132 | 4/198 | 2/273 |
| 87 | 186/267 | 228/755 | 207/511 | 206/452 | 42/484 | 1/609 | 1/523 |
| Yecora Rojo | 28/758 | 132/529 | 80/525 | 61/680 | 103/533 | 6/766 | 0/136 |
| NO.49 | 138/605 | 205/412 | 172/009 | 168/735 | 66/807 | 2/818 | 1/018 |

**Table 2: Correlation between drought tolerance indices with grain yield under normal irrigation and drought stress conditions**

| | Ys | Yp | MP | GMP | TOL | SSI |
|---|---|---|---|---|---|---|
| Yp | 0/747** | | | | | |
| MP | 0/915** | 0/952** | | | | |
| GMP | 0/944** | 0/923** | 0/996** | | | |
| TOL | -0/019ns | 0/651** | 0/386** | 0/310** | | |
| SSI | -0/404** | 0/270* | -0/022ns | -0/100ns | 0/867** | |
| STI | 0/908** | 0/912** | 0/982** | 0/985** | 0/312** | -0/100ns |

*, ** and ns *respectively significance at p < 0.05 ,< 0.01 and non-significance*

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