# High vs. Low Stress Yield Test Environments for Identifying Drought Tolerant Durum Wheat Cultivars

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## Summary

*The objective of this study was to select for drought tolerance among 10 durum wheat (*Triticum durum *DESF.) cultivars. Observation of tolerance was based upon yield depressions due to water stress. The yield trials were conducted under rainfed conditions during two unfavorable growing seasons and two favorable years in a semi-arid region of Tunisia. Genotypic response to water stress was assessed by stress and drought indices. Varietal adaptation was measured by stability parameters. Mean productivity and tolerance to drought were also used in order to characterize genotypic response. The values of stability parameters differed to a great extent among genotypes. Some cultivars were identified as resistant to drought. Conversely, others were found to be drought susceptible. Significant differences were observed among cultivars in their mean productivity. Tolerance to drought ranked genotypes differently from the ranking based on mean productivity. Each selection criterion used resulted in different types selected.*

## Résumé

*L'objectif de cette étude était de sélectionner pour la tolérance à la sécheresse parmi 10 cultivars de blé dur (*Triticum durum *DESF.) en se basant sur la réduction du rendement due au stress hydrique. Les essais du rendement ont été conduits sous des conditions pluviales pendant deux années défavorables et deux années favorables dans une région semi-aride de la Tunisie. La réponse génotypique au stress hydrique fut caractérisée par des indices de tolérance à la sécheresse. L'adaptation variétale fut mesurée par les paramètres de stabilité. La productivité moyenne et la tolérance à la sécheresse ont été aussi utilisées afin de caractériser la réponse génotypique. Les paramètres de stabilité ont largement différé parmi les génotypes testés. Certains cultivars résistants à la sécheresse ont été détectés alors que d'autres lui étaient sensibles. Des différences significatives ont été observées parmi les variétés dans leur productivité moyenne. Le classement des variétés selon la tolérance à la sécheresse a différé du classement basé sur la productivité moyenne. Chaque critère de sélection a résulté en différents types retenus.*

## Introduction

Yield is an important criterion in evaluating adaptability. Plant breeders continue to search for ways to increase the efficiency of selection for seed yield. One approach has been to examine different types of environments in which yield tests are conducted. The most desirable approach would be to choose testing sites that are representative of the production areas where a breeder wishes to improve yields (10).

There is a definite expectation of the crop's performance in relation to environmental worth. In general, crop yield increases with improvement in environmental factors. A desired cultivar must possess the ability not only to take advantage of an improved or a favorable environment but also to yield satisfactorily in an adverse environment.

The relationship between yield and environment was quantified by several researchers who described techniques for measuring adaptation in variable environments. Stability parameters for comparing cultivars were calculated (1, 2, 5, 8, 9).

Previous investigations used a wide range of environmental conditions in order to characterize genotypic response. However, field selection under stress and non-stress conditions allows the establishment of a selection index that may be accurate and rapid enough so it may be applied to large numbers of lines. This index may be successfully used to screen large numbers of cultivars and may characterize genotypic response to water stress (23).

In Tunisia, Durum wheat (*Triticum durum* DESF.) is grown under rainfed conditions. The variability of rainfall amount and distribution over years is usually unpredictable. Consequently, average yield is low, irregular and varies with prevailing weather conditions. The identification of high-yielding cultivars lowers risk and raise profit for the grower.

The objective of this experiment was to compare drought tolerance of 10 durum wheat cultivars. Yield expression in different rainfed conditions was considered as the basis for identifying drought tolerant cultivars and was used for selection of high yielding genotypes under both stress and non-stress conditions.

## Material and Methods

Fields experiments were conducted during two stressful (1985/86 and 1987/88) and two favorable (1986/87 and 1990/91) growing seasons at the Ecole Supérieure d'Agriculture du Kef Experimentation Station (Tunisia).

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Annual precipitation at the site has historically fluctuated between 300 mm and 500 mm with most rainfall occurring during the period between 1 October and 30 April. Monthly precipitation data for the four growing seasons are given in Table 1. The soil at the test site is a sandy clay loam, not well developed, deep, and a fine textured vertisol. It has a field capacity of 27% and a wilting point of 12%. Prior to each trial the site was a fallow. Field tillage consisted of a deep fall plowing followed by a good seed bed preparation. Fertilizers were applied at the recommended rates (based on soil test results) for optimum wheat yield.

**Table 1 : Monthly precipitation (mm) for the four growing seasons**

| Months | Growing seasons | | | |
|---|---|---|---|---|
| | 1985/86 | 1986/87 | 1987/88 | 1991/92 |
| September | 11.4 | 39.5 | 0.0 | 56.5 |
| October | 14.4 | 60.8 | 16.7 | 52.6 |
| November | 15.3 | 41.7 | 30.2 | 32.6 |
| December | 13.4 | 66.3 | 5.7 | 16.1 |
| January | 58.0 | 33.1 | 38.8 | 28.4 |
| February | 46.9 | 72.9 | 11.2 | 62.3 |
| March | 71.1 | 55.8 | 24.7 | 31.1 |
| April | 22.0 | 60.6 | 33.2 | 95.8 |
| May | 15.1 | 54.3 | 84.0 | 82.1 |
| June | 34.3 | 6.9 | 27.4 | 27.7 |
| Total | 301.9 | 491.9 | 271.9 | 485.2 |

Ten cultivars of durum wheat representing a wide range of genetic variability for morphological and physiological traits were chosen to be included in this study. These cultivars were : Karim, INRAT 69, Chili, Ben Bechir, Badri, Maghrebi, Stork, Diego, Cardeno, and Oscar. The first six cultivars are Tunisian registered cultivars widely grown in the semi-arid regions of Tunisia. Stork is a cultivar released by ICARDA (International Center for Agricultural Research in the Dry Areas) whereas Diego, Cardeno and Oscar were introduced from Spain. The cultivars were planted on 28 November 1985, 6 December 1986, 3 December 1987 and 12 December 1991 at a rate of 100 kg/ha and 0,20 m row spacing in 6 row plots 5 m long. Before harvesting plots were trimmed to four row plots 4 m long in order to avoid border effects. Plots were kept weed-free by a periodic hand weeding. The experimental plots were arranged in a randomized complete block design with four replications. Plots were 50 cm isolated from each other in order to prevent competition. At maturity, the center four rows of each plot were harvested with a hege plot combine and yield adjusted to 13% moisture.

To assess genotypic responses to water stress, a stress and a drought index for seed yield were computed for each cultivar (3). The stress index of a given cultivar is defined as the ratio of its mean seed yield in the stressful years to that in the favorable years. The corresponding drought index is the ratio of the stress to the overall population mean of stress indices. Varietal adaptation of each cultivar was assessed by using two indices (2). The first one is the regression coefficient (b-value) of yields of the variety considered on the mean yield of all varieties at each environment. The second one is the mean yield of each variety over all environments (mean productivity). Another parameter was computed. This parameter is tolerance to drought defined as the average yield difference between the non-stressful and stressful environmental conditions.

The data obtained for each measured trait were subjected to an analysis of variance (ANOVA). Years were considered random effects and cultivars fixed effects. Appropriate F tests were conducted for evaluating the statistical significance. The least significant difference (LSD) value was used for comparing means.

## Results and Discussion

Significant effects of genotype on seed yields were observed during each year. When data were pooled across years, significant year and genotype x year effects on grain yield were detected. There was a large difference in seed yield between the two wet and the two dry years (Table 2). Mean seed yields (pooled over cultivars) of the stressful and non-stressful years were 624 kg/ha and 3583 kg/ha, respectively, showing an important reduction (82,6%). These results illustrate that drought is a serious limitation to wheat production in Tunisia. The low yield potential of the cultivars tested during the dry years indicate that there is an urgent need to develop better adapted cultivars.

**Table 2 : Seed Yield (kg/ha) of the durum wheat cultivars grown under droughty and favorable growing seasons**

| Cultivars | Growing seasons | | | |
|---|---|---|---|---|
| | 1985/86 | 1986/87 | 1987/88 | 1991/92 |
| Karim | 346 | 4148 | 320 | 5278 |
| INRAT 69 | 544 | 2926 | 522 | 3346 |
| Chili | 366 | 2503 | 314 | 2807 |
| Ben Bechir | 415 | 3958 | 412 | 4436 |
| Badri | 989 | 2344 | 827 | 3004 |
| Maghrebi | 940 | 3091 | 749 | 3347 |
| Stork | 1096 | 4094 | 894 | 4487 |
| Diego | 1059 | 3619 | 792 | 3921 |
| Cardeno | 642 | 3780 | 608 | 3442 |
| Oscar | 332 | 3467 | 307 | 3662 |
| Mean | 673 | 3393 | 575 | 3773 |
| LSD ($P < 0.05$) | 239 | 468 | 209 | 522 |

Under stress conditions the difference in yield among genotypes were small (the maximum difference between two genotypes was 764 kg/ha and 587 kg/ha in the two dry years, respectively) while under non-stress conditions these differences were larger (1804 kg/ha and 2471 kg/ha). Hence, the yield range under optimal water supply was about three times the range under severe water stress. These results indicate that maximal yield potential is more readily expressed in the absence of stress. Similar results were reported (4, 6).

Because genotype x year interaction effects on seed yield were highly significant varietal adaptation was characterized with the stability index (b-value) (2). Cultivars could be grown in two extreme environmental conditions (as in this study) to measure stability (7).

Stability indices (b-values) for seed yield differed to a great extent among genotypes (Table 3). Badri (b = 0.61), Chili (b = 0.78) and Maghrebi (b = 0.80) with low b-values were the most stable cultivars. Karim (b = 1.49), the most widely grown cultivar in Tunisia, was the least stable cultivar but it had the greatest yield potential in an abundant soil moisture environment. The remaining cultivars had intermediate stability.

**Table 3 : Stability parameter (SP), mean productivity (MP, kg/ha), Stress index (SI), drought index (DI), and tolerance to drought (TD, kg/ha) of the cultivars tested**

| Cultivars | SP | MP | SI | DI | TD |
|---|---|---|---|---|---|
| Karim | 1.49** | 2523 | 0.07 | 0.39 | 4380 |
| INRAT 69 | 0.88* | 1835 | 0.17 | 0.94 | 2603 |
| Chili | 0.78** | 1498 | 0.13 | 0.72 | 2315 |
| Ben Bechir | 1.28** | 2305 | 0.10 | 0.56 | 3817 |
| Badri | 0.61** | 1791 | 0.34 | 1.89 | 1766 |
| Maghrebi | 0.80** | 2032 | 0.26 | 1.44 | 2374 |
| Stork | 1.11** | 2643 | 0.23 | 1.28 | 3305 |
| Diego | 0.96 | 2348 | 0.25 | 1.39 | 2844 |
| Cardeno | 0.99 | 2118 | 0.17 | 0.94 | 2986 |
| Oscar | 1.09 | 1942 | 0.09 | 0.50 | 3306 |
| Mean | 1.00 | 2103 | 0.18 | 1.00 | 2970 |
| LSD (P < 0.05) | | 345 | 0.07 | 0.11 | 456 |

*, ** Significantly different from 1.0 at the 5% and 1% levels of probability, respectively

There were significant differences among cultivars in both stress and drought indices (Table 3). Cultivars associated with high stress indices were also associated with high drought indices and vice versa. Badri, Maghrebi, Diego, and Stork with drought indices of 1.89, 1.44, 1.39 and 1.28, respectively, were the most drought resistant cultivars in this population. Conversely, the cultivars Karim, Oscar, and Ben Bechir with drought indices of 0.39, 0.50 and 0.56, respectively, were the most drought susceptible cultivars. The remaining cultivars with drought index values close to 1.0 were intermediate between resistance and susceptibility in their reaction to drought. Karim, a cultivar widely grown in Tunisia even in the low rainfall areas, appeared in this experiment as the most drought susceptible cultivar and therefore should not be grown in the drought prone areas.

Mean productivity may help breeders to develop cultivars that produce high yield under both stress and non-stress conditions. This parameter is useful in environments where moisture limitations to yield are unpredictable from year to year. Significant differences were observed among the cultivars in their mean productivity (Table 3). The ranking of genotypes based on their drought indices was different from their ranking based on mean productivity. For example, Karim was associated with high mean productivity (2523 kg/ha) yet, it was the most drought susceptible cultivar with a stress index of 0.07 and a drought index of 0.39. Stork was associated with the highest mean productivity (2643 kg/ha).

Tolerance to drought ranked also Karim and Ben Bechir among the least drought tolerant cultivars and Badri. Chili and Maghrebi among the most drought tolerant cultivars (Table 3). These results indicate that cultivars selected for high yield in optimal moisture conditions will not necessarily be superior when exposed to water stress.

Results of this study indicate that it is important that plant breeders be aware of the implications of selection criteria used in order to detect drought resistant cultivars based on their performance under favorable and non favorable situations. As illustrated in this study, each selection criterion resulted in different selected genotypes.

## Conclusion

These results indicate that cultivars selected for high yield in optimal moisture conditions will not necessarily be superior when exposed to water stress. Thus, selection for high yielding ability under stress conditions may disregard the yield potential under favorable environmental conditions. Under stress conditions, differences in yield among genotypes may be due to factors other than yield potential. Under such conditions maximum genetic potential is not fully expressed; a large portion of the observed phenotypic variance is attributable to the effects of the environment and the genotype x environment interaction. Under water stress conditions the stress may be so severe that the yield does not differ, considerably, among genotypes. Thus, in such cases, screening for yield per se, may not be effective. This breeding strategy should be carried out in areas where water stress is expected to occur reliably and uniformly every growing season. On the other hand, selection for drought resistance, drought tolerance, yield stability, or mean productivity must be predicated on the environment where the genotypes are to be grown. If yield under stress must be improved then selection must be made on drought index or tolerance to drought. If drought is unpredictable, the selection for mean productivity and yield stability are desirable yet, ranking of genotypes based on their mean productivity is different from the ranking based on drought indices.

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