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# The relationship between productivity and some drought tolerance indicators for several cultivars of bread wheat

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**Abstract:** The research was conducted in Tartous Governorate during the two agricultural seasons (2018–2019 and 2019–2020) under control conditions, the aim of the research is to study the relationship between the productivity of five promising strains of bread wheat ('ACSAD 1256', 'Douma 58847', 'Douma 58585', 'Douma 64453', 'ACSAD 1149') and two cultivars ('Douma 2' and 'Douma 4') and some quantitative indicators of drought: stress tolerance index (*STI*), mean of productivity (*MP*), modified stress tolerance index (*MSTI*), and relative yield (*RY*).

Cultivation was carried out in pots filled with light sandy silty soil, and three treatments of 70, 50, and 30% of the field capacity were applied in addition to the control and with three replications for each treatment.

The strains 'Douma 58585' and 'Douma 58847' gave high yield values for grain in the two agricultural seasons. It was also found that there were significant differences between the two seasons in yield between the control and drought stress factors and drought tolerance indicators, such as stress tolerance index, modified stress tolerance index (*MSTI*), mean of productivity (*MP*), and relative yield (*RY*).

On the other hand, a positive and strong relationship was found between *STI*, *MSTI*, and *MP* in both treatments and both seasons. The research concluded that the best indicators, which were related to the productivity, whether in the control or transactions and in the two growing seasons together, are *STI* and *MP*, which are promising indicators in the classification of stress-tolerant cultivars or strains.

**Keywords:** bread wheat, drought indicators, drought stress, grain yield

## INTRODUCTION

Based on global climate scenarios, the Mediterranean Sea has been classified as one of the most responsive regions to climate change [Giorgi 2006]. It will become hotter and drier [Bates *et al.* 2008; Pachauri, Reisinger 2008]. This will negatively affect the rate of rainfall and its distribution in arid and semi-arid regions and lead therefore to a change in the frequency of drought rates. Scientists tried to find appropriate strategies to reduce the difference between the actual yield and the actual capacity of crops in these areas [Ort 2002].

Wheat is the most widely grown cereal crop in the world, accounting for one-fifth of all human food calories, it is a very important crop and the second most consumed food grain by humans in Mediterranean Basin [Ali *et al.* 2012; Farooq *et al.* 2014; Hawkesford *et al.* 2013].

Wheat is widely used in the production of bread, cookies, and other baked goods. People prefer wheat products such as crumpets, flake, and flour grain as roasted grain, and it is important to feed livestock because of their high nutritional value.

During the growth period, about 32% of wheat in developing countries is exposed to various types of stresses, the most important of which is drought stress. Thus, the shape of the plant, its physiological functions and its chemistry are negatively affected, leading to a significant loss of the crop [Rawatiya, Kasal 2021].

Fernandez [1992] developed a stress tolerance index (*STI*) to determine cultivars with high yields in both stressful and normal conditions, while FARSHADFAR and SUTKA [2003] proposed a modified stress tolerance index (*MSTI*) that takes into account the environmental conditions that led to noticeable changes in cultivar yields in all environments. Therefore, its use can be helpful in selecting tolerant cultivars. FERNANDEZ [1992] also divided the strains and cultivars based on their reactions under stress and normal conditions into four groups: group A includes the cultivars with high yield under normal and stressful conditions, group B includes the cultivars with high yield under normal conditions only (non-stressed), group C includes cultivars with good grain yield only in stress conditions, and group D includes cultivars with low yield in both conditions. HALL [1993] defined drought tolerance as the relative yield of a cultivar compared to other cultivars grown under the same stress conditions, while BLUM [1988] measured the sensitivity of a cultivar to drought based on the decrease in grain yield under drought conditions. NOORI *et al.* [2012] conducted an experiment to study the high performance of the combined use of climate factors and drought indices to predict the expected wheat yield in a semi-arid region in western Iran for several months before harvest. The results showed that *STI* had a major role in the prediction models of yield regression compared to climate factors. It was also observed that the shorter the time interval between forecasting and harvesting, the more accurate the yield prediction will be. SHAHRYARI *et al.* [2008] showed in their research on wheat the importance of using mean of productivity (*MP*) in selecting tolerant cultivars but finding equal values for this evidence in different plant groups is very difficult when taking into account the tolerance index and mean of productivity. The cultivars that give the highest productivity may not be found in the lowest groups in relation to the tolerance index, and therefore the selection of the tolerant varieties is difficult (as the lower the value of the tolerance index, the more bearable the cultivars), so they stressed the need to use *STI* and *MP* proposed by FERNANDEZ [1992], but they showed that we may find difficulties in understanding and explaining the differences in the results when applying this geometric equation, which may be attributed to natural or environmental reasons.

An experiment was conducted in southern Turkey [ERDEMCI 2018] to select drought-tolerant chickpea cultivars under stressful and non-stressed conditions by using *MP*, *STI*, *MSTI* and relative yield (*RY*) as drought indicators. The results showed a significant and positive relationship under both stress and non-stress conditions between productivity and *MP*, *STI*, *MSTI* indices and a negative relationship with *RY*. In addition, there were significant differences in yield under both conditions.

In an experiment conducted by ANWAAR *et al.* [2020] on 50 wheat strains and cultivars to determine their sensitivity and tolerance to drought, the results showed that grain yield was negatively correlated with tolerance against stress (*TOL*), drought index (*DI*), stress susceptibility index (*SSI*), *MP* and engineering yield (*GMP*) under drought conditions. These results confirmed that tolerant strains and cultivars can be selected by elevated *MP*, *GMP*, *SSI*, and *TOL* values. The objective of this experiment was to study drought tolerance indicators of different bread wheat cultivars and strains to distinguish drought-tolerant cultivars and to study the correlation between drought tolerance indicators.

## MATERIALS AND METHODS

The research was conducted during the two winter agricultural seasons (2018–2019 and 2019–2020) in a greenhouse in Tartous governorate, which is 300 m above sea level, noting that the laboratory work was carried out in the laboratories of the Faculty of Agriculture at Tishreen University.

Five promising strains of bread wheat were used: 'ACSAD 1149', 'ACSAD 1256', 'Douma 58847', 'Douma 58585', and 'Douma 64453' and two approved cultivars ('Douma 2', 'Douma 4'), as they were approved for irrigated and rainfed agriculture in the first settling zone, which is characterised by stable production, cold tolerance, and early ripening, obtained from the General Authority for Scientific Agricultural Research in Damascus. The experiment included three drought treatments: 70, 50, and 30% of the field capacity.

The planting was carried out in pots (diameter 20 cm and height 18 cm), so that the area of the pot was 0.0314 m$^2$. In controlled conditions (the plastic house) the temperature in the morning ranged between 17 and 28°C, and in the afternoon ranged between 20 and 35°C, the humidity in the morning ranged between 34 and 83%, and in the afternoon between 26 and 83%. At the beginning of the experiment, the pot was filled with 5 kg of dry light siliceous sand soil, and 10 wheat grains of each strain or class of the studied strains and items were planted in each pot, with a depth of 5 cm. The final pot number was 63 pot (7 cultivars×3 drought treatments×3 replications).

The experiment was designed in a randomised complete block pattern with three replications. The experiment aimed to study the behaviour of wheat cultivars and strains with water stress at 50 and 30% of the field capacity by soil weight method. The data were analysed using the statistical analysis program Genstat12 by conducting an analysis of variance (ANOVA), followed by Fisher's least significant differences postdoc test when the differences were substantial, and Pearson correlation coefficient between indicators and grain yield during the two seasons.

**Experimental conditions.** The temperature and humidity inside the greenhouse were measured twice a day, as clear changes in temperature and relative humidity were recorded during the morning and afternoon periods during the days of the experiment. Measurements were taken in the stage (45Z, boots swollen) that follows flowering by ten days, and the stage (70Z, kernel water ripe, no starch) that follows maturity by ten days.

**Field capacity.** Calculated by the gravimetric method the completely dry soil (105°C) was moistened with increasing rates of water 10, 15, 20, 25, and 30% of the field capacity by weight and incubated in closed nylon bags for 24 h, then measured the relative humidity using a hygrometer. The field capacity (29% by weight) and the permanent wilting point (10% by weight) were also estimated by means of a membrane pressure device in the soil analysis laboratory (Beit Kammuna Research Center). After taking the weight of the pot with the soil when it reaches the saturation stage (100%) and through it, the weight of the soil needed to reach the required parameters (70, 50, 30%) of the field capacity was calculated. By calculating the depth of the net irrigation water where it was irrigation by adding the required weight of water to the soil surface while maintaining a constant weight during the 45 Z and 70 Z phases.

**The studied indicators:**

– productivity indicators. The plants were harvested at maturity (ten plants), and the grains of all the spikes were weighed in each treatment and for each replication separately in both seasons, and the weight of the grains of the spikes was divided by the number of plants and according to the average, then the productivity was calculated in $g \cdot m^{-2}$;

– drought indicators. The following equations (Tab. 1) were used to calculate the drought indicators in the greenhouse:

**Table 1.** The equations for calculating drought indicators

| Drought indicator | | Source |
|---|---|---|
| explanation | equation | |
| $STI = [YP \cdot YS/\ddot{Y}P\ 2]$ | drought tolerance index | Fernandez [1992] |
| $MP = (YP - YS)/2$ | mean of productivity | Shahryari *et al.* [2008] |
| $MSTI = K(YP \cdot YS)/\ddot{Y}P^2$ | modified stress tolerance index | Shahryari *et al.* [2008] |
| $K = YS^2 \cdot \ddot{Y}S^2$ | stress index | Fernandez [1992] |
| $RY = (YS/YP)$ | relative production | Fray [1981] |

Explanations: *YS* = yield under stress conditions, *YP* = yield under control conditions, *ŸS*, *ŸP* = mean yields for all models studied under stress and control conditions, respectively.
Source: own elaboration based on the stated studies.

## RESULTS AND DISCUSSION

The results of the variance analysis for the two agricultural seasons (2018–2019 and 2019–2020) in Table 2 indicated that there were significant differences in the interaction between cultivars and season ($p < 0.05$) for the grain yield under control and stress conditions in the two treatments 30 and 50% of the field capacity for each of the drought indicators: *STI*, *MP*, *MSTI*, and *RY*. Also, significant differences were found between strains in grain yield under control and stress conditions for all indicators of drought tolerance studied.

There were significant differences between the two seasons ($p < 0.05$) in grain yield under the control and stress conditions, and drought tolerance criteria *STI*, *MP*, *MSTI* and *RY* (Tab. 2).

The results showed that the average value of grain yield for 'ACSAD 1256' was 599 $g \cdot m^{-2}$. This strain recorded a significant increase in the average value of grain yield in the control treatment as compared to the rest of the strains and cultivars ('ACSAD 1149', 'Douma 58585', 'Douma 58847', 'Douma 64453', 'Douma 2', 'Douma 4') (Tab. 3).

The results of Table 3 showed a decrease in the average value of grain yield under stress conditions compared to the control treatment. The strains and cultivars showed different reactions towards drought stress. The values of grain yield in the strain 'Douma 58585' reached 488 $g \cdot m^{-2}$ at 50% of the field capacity and 210 $g \cdot m^{-2}$ at 30% of the field capacity compared to the rest of the strains and cultivars. According to Mahasna [2012], such decrease in grain yield values might be attributed to the decline in the soil water content, the reduction in the efficiency of the cultivars and the prevention of the formation of fruitful straws due to the lack of available photosynthetic products, which will lead to the low number of grains and, consequently, the decrease in grain yield. Our results are in agreement with the results of Arisnabarreta and Miralles [2008], who found that the final grain weight depends on the weight of the carpel at the flowering stage, due to the effect of drought on the emergence of florets and the decrease in the weight of the carpel at the pollination stage.

As for the drought indices, the results of Table 3 showed that the highest values of *STI* were recorded for the strain 'Douma 58585' (3.24 and 1.39) for 50 and 30% treatments, respectively compared to the rest of the cultivars and strains. This result is consistent with Bazrafshan *et al.* [2009], who found that the best criterion for evaluating drought tolerance is *STI* in addition to the geometric mean yield index under moderate and severe stress conditions, and with the results of Modhej *et al.* [2007], who found that the wheat cultivars that gave the highest yield under ideal conditions and under stress conditions gave the highest value of *STI*.

As for *MSTI*, the highest value was 1.89 for 'Douma 58585', followed by 'Douma 58847' (1.76) and 'Douma 4' (1.68) versus the lowest of 0.13, 0.82, 0.32, and 0.18 were recorded in the cultivars 'ACSAD 1149', 'ACSAD 1256', 'Douma 64453', and 'Douma 2' when treatment 50% and the treatment 30% behaved the same as treatment 50%, and higher values were recorded for the strain 'Douma 58585', 'Douma 58847', 'Douma 4' (1.26, 0.74, 0.44, respectively). Both treatments showed significant differences in the mean values of the modified drought tolerance coefficient

**Table 2.** Analysis of co-variance of grain yield under control conditions *YP* and *YS*, and drought tolerance criteria for cultivars of soft wheat for the two seasons (2018–2019 and 2020–2019)

| Source of variation | *YP* | *YS* 50 | *YS* 30 | *STI* 50 | *STI* 30 | *MP* 50 | *MP* 30 | *MSTI* 50 | *MSTI* 30 | *RY* 50 | *RY* 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0.08* | 0.14* | 0.0031* | 87.9* | 95.9* | 767.4* | 902.0* | 237.0* | 345.0* | 0.09* | 0.06* |
| Cultivar | 0.033* | 0.07* | 0.07* | 140.6* | 162.1* | 323.0* | 246.4* | 129.9* | 135.0* | 0.29* | 0.19* |
| Year×cultivar | 0.18* | 0.19* | 0.01* | 566.0* | 290.0* | 79.0* | 65.0* | 49.8* | 63.0* | 0.48* | 0.33* |
| Replication | 0.40 | 0.24 | 0.60 | 806.0 | 133.0 | 0.19 | 0.07 | 17.0 | 19.9 | 0.6 | 0.72 |
| Replication×cultivar | 0.78 | 0.60 | 0.45 | 680.0 | 715.6 | 0.59 | 0.13 | 0.38 | 0.9 | 0.36 | 0.57 |

Explanations: *YP* = yield under control conditions, *YS* 50 = yield under stress (50% of field capacity), *YS* 30 = yield under stress (30% of field capacity), *STI* = stress tolerance index, *MP* = mean of productivity, *MSTI* = modified stress tolerance index, *RY* = relative yield, * = significant differences at the level of significance on the average grain yield ($p < 0.05$).
Source: own study.

**Table 3.** Indicators of drought tolerance for the agricultural seasons 2018–2019 and 2019–2020

| Cultivars | *YP* | *YS* 50 | *YS* 30 | *STI 50* | *STI* 30 | *MP* 50 | *MP* 30 | *MSTI* 50 | *MSTI* 30 | *RY* 50 | *RY* 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 'ACSAD 1149' | 370$^{e}$ | 266$^{f}$ | 129$^{e}$ | 1.09$^{d}$ | 0.53$^{e}$ | 0.52$^{d}$ | 1.20$^{d}$ | 0.13$^{g}$ | 0.18$^{e}$ | 71.89$^{f}$ | 34.86$^{d}$ |
| 'ACSAD 1256' | 400$^{d}$ | 375$^{d}$ | 145$^{d}$ | 1.66$^{c}$ | 0.64$^{d}$ | 0.12$^{g}$ | 1.27$^{c}$ | 0.82$^{d}$ | 0.27$^{d}$ | 93.46$^{a}$ | 36.25$^{a}$ |
| 'Douma 58585' | 599$^{a}$ | 488$^{a}$ | 210$^{a}$ | 3.24$^{a}$ | 1.39$^{a}$ | 0.55$^{c}$ | 1.94$^{b}$ | 2.72$^{a}$ | 1.26$^{a}$ | 81.46$^{c}$ | 35.05$^{c}$ |
| 'Douma 58847' | 568$^{c}$ | 430$^{b}$ | 179$^{b}$ | 2.71$^{b}$ | 1.12$^{b}$ | 0.69$^{b}$ | 1.94$^{b}$ | 1.76$^{b}$ | 0.74$^{b}$ | 71.78$^{g}$ | 31.51$^{e}$ |
| 'Douma 64453' | 320$^{f}$ | 267$^{e}$ | 114$^{f}$ | 0.94$^{e}$ | 0.40$^{f}$ | 0.26$^{f}$ | 1.03$^{e}$ | 0.32$^{e}$ | 0.10$^{f}$ | 83.43$^{b}$ | 35.62$^{b}$ |
| 'Douma 2' | 318$^{g}$ | 244$^{g}$ | 103$^{g}$ | 0.86$^{f}$ | 0.36$^{g}$ | 0.37$^{e}$ | 1.07$^{f}$ | 0.18$^{f}$ | 0.07$^{g}$ | 76.72$^{d}$ | 35.62$^{b}$ |
| 'Douma 4' | 580$^{b}$ | 420$^{c}$ | 150$^{c}$ | 2.70$^{b}$ | 0.96$^{c}$ | 0.80$^{a}$ | 2.15$^{a}$ | 1.68$^{c}$ | 0.44$^{c}$ | 72.41$^{e}$ | 25.86$^{f}$ |
| *LSD* (5%) | 0.003* | 0.007* | 0.092* | 0.013* | 0.05* | 0.044* | 0.015* | 0.009* | 1.00* | 0.88* | 0.027* |
| *CV* (%) | 3.0 | 1.0 | 2.5 | 3.0 | 1.0 | 2.5 | 1.9 | 1.8 | 3.0 | 4.0 | 3.8 |

Explanations: a, b, c, … = significant differences between cultivars and strains, *YP*, *YS* 50, *YS* 30, *STI*, *MP*, *MSTI*, *RY*, * as in Tab. 2.
Source: own study.

index at the significance level ($p < 0.05$). The results indicate that the strains 'Douma 58585' and 'Douma 58847' have achieved the best values of *STI* and *MSTI*, therefore, they can be classified as the most tolerant, while *MP* values recorded a difference between the two treatments 30 and 50%. The cultivar 'Douma 4' had the highest value (0.80) of *MP* at treatment 50% versus (1.94) for the two strains 'Douma 58585' and 'Douma 58847'.

The result of correlation indicators during the two seasons showed that the grain yield in the control treatment was productivity index at stress treatment 30% ($r$ = 0.88*). This result is in agreement with Maleki *et al.* [2008] and Golabadi *et al.* [2006] who confirmed that high values of *STI* and *MSTI* can be relied upon to select drought-tolerant strains and cultivars.

The drought tolerance index was significantly positively associated at 50 and 30% with *MP* and *MSTI* for both treatments, 50 and 30%, while *MP* was significantly negatively correlated with the *RY* ($r$ = −0.82*) (Tab. 4).

**Table 4.** Correlation relationship according to Pearson coefficient between indicators and grain yield during the two seasons 2018–2019 and 2019–2020

| Cultivar | *YP* | *YS* 50 | *YS* 30 | *STI* 50 | *STI* 30 | *MP* 50 | *MP* 30 | *MSTI* 50 | *MSTI* 30 | *RY* 50 | *RY* 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *YP* | 1 | 0.945* | 0.888* | 0.987* | 0.960* | 0.736* | 0.983* | 0.947* | 0.855* | −0.296 | −0.581* |
| *YS* 50 | | 1 | 0.940* | 0.980* | 0.958* | 0.488* | 0.889* | 0.969* | 0.891* | 0.026 | −0.392 |
| *YS* 30 | | | 1 | 0.932* | 0.974* | 0.468* | 0.790* | 0.947* | 0.974* | −0.030 | −0.170 |
| *STI* 50 | | | | 1 | 0.982* | 0.634* | 0.949* | 0.983* | 0.907* | −0.163 | −0.482* |
| *STI* 30 | | | | | 1 | 0.611* | 0.895* | 0.983* | 0.963* | −0.173 | −0.347 |
| *MP* 50 | | | | | | 1 | 0.798* | 0.547* | 0.467* | −0.827** | −0.728** |
| *MP* 30 | | | | | | | 1 | 0.890* | 0.756* | −0.383 | −0.711** |
| *MSTI* 50 | | | | | | | | 1 | 0.952* | −0.082 | −0.367 |
| *MSTI* 30 | | | | | | | | | 1 | −0.074 | −0.126 |
| *RY* 50 | | | | | | | | | | 1 | 0.506* |
| *RY* 30 | | | | | | | | | | | 1 |

Explanations: ** = significant correlation between drought tolerance indicators, *YP*, *YS* 50, *YS* 30, *STI*, *MP*, *MSTI*, *RY*, * as in Tab. 2.
Source: own study.

significantly positively associated with *STI*, *MP* and *MSTI* under drought stress conditions. This result is consistent with the results of Zamski and Grumberger [1998], that the strains and cultivars that showed a high grain yield under the control conditions showed a high yield under stress conditions. This finding was also confirmed by previous studies [Bennani *et al.* 2017; Dadbakhsh *et al.* 2011; Mau *et al.* 2019].

The grain yield at 50% was also correlated with the values of *STI* in both treatments 50 and 30%, ($r$ = 0.98*, $r$ = 0.95*, respectively), and a significant positive correlation with the *MSTI* index in both treatments ($r$ = 0.96*, $r$ = 0.89*) and with mean

## CONCLUSIONS

Drought is the most extreme, but most common problem facing global wheat producers. Recruitment of drought-tolerant, high-yielding strains and cultivars is the appropriate way to reduce the effects of drought. Assessment of strains and cultivars using physiological characteristics under 70% of field capacity and drought conditions 50 and 30% of field capacity is an appropriate way to achieve this goal. In this study, two irrigation systems (control 70% of field capacity and drought treatments 30 and 50% of field capacity) were used to evaluate strains and cultivars with different drought indices such as stress tolerance index (*STI*), mean of productivity (*MP*), modified stress tolerance index (*MSTI*) and relative yield (*RY*).

Statistical analysis shows that strains and cultivars 'Douma 58585' and 'Douma 58847' were more tolerant of drought in both seasons and are recognised as suitable for both natural and dry conditions due to the slight decrease in their grain yield. Therefore, they can be exploited to transfer tolerance genes to other strains and cultivars and can be used in drought control programs.

In the second season 'Douma 2' and 'Douma 64453' turned out to be more sensitive to drought stress due to the high loss of yield.

The search results showed that the best parameters that were positively correlated with grain yield in the control and stress conditions are such indicators as stress tolerance index (*STI*), mean of productivity (*MP*), modified stress tolerance index (*MSTI*), which can be used in varietal sifting experiments for drought.

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