Assessment of physiological traits associated with yield improvement in wheat (*Triticum durum*) under rainfed conditions

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**Abstract**

The current study aims at associating yield and yield parameters with physiological traits (membrane stability index, relative water content, chlorophyll content and chlorophyll fluorescence) of three wheat varieties grown in Southern Syria under 400 mm and 291 mm annual rainfall at different stages of plant growth. Modern durum wheat variety (douma3) showed the best performance for all physiological traits tested and the highest yield and yield components compared to intermediate (sham3) and old variety (hourani). Douma3 performed better than the other two varieties especially at low rainfall zone (291 mm) and this was associated with higher values of membrane stability. The study proved that yield improvement in modern wheat varieties relied on improvement of physiological performance particularly under water deficit condition.

**Introduction**

Wheat (*Triticum aestivum*) represents about 30\% of the world’s cereal area, with over 220 million ha cultivated worldwide, often under abiotic stress (Cossani and Reynolds, 2012). It is one of the first domesticated food crops that represent the first source of calories and an important source of proteins in developing countries. World wheat production increased at a rate of 3.3 percent per year between 1949 and 1978.

The increase was due to both an expansion of production area and increased yields. However, in the sixties, yield increase was mainly due to the use of improved varieties coupled with a greatly expanded use of irrigation, pesticides and fertilizers. The rate of increase in world wheat production slowed down to 1.5 percent per year between 1982 and 1991, one exception being China, which maintained a rate of increase in production of 2.6 percent per year and became the world's largest wheat producer. Also, wheat production increased at nearly 3 percent per year in India and Pakistan during the same period (Monneveux et al., 2012). Knowledge of changes...
associated with advances in crop productivity is essential for understanding yield-limiting factors and developing strategies for future improvement (Donmez et al., 2001). While many traits have been studied for their use in breeding for drought resistance, there is a general consensus among breeders that only a few of them can be recommended for use in practical breeding programs. For example, Reynolds et al., (2001) recommended the use of flowering and maturity dates, spike fertility, changes in green biomass and canopy temperature. In practical terms, these traits seem valuable when breeding for higher yield potential and adaptation to some degree of stress. Many drought-adaptive traits have been investigated in wheat. However, association of these traits with genetic gains for yield under drought has been poorly tested and documented. Most difficulties encountered in the identification of accurate drought tolerance traits are due to the fact that wheat is cultivated under very different climatic conditions and faces very different drought scenarios worldwide. The objective of this paper is to analyze some physiological traits and their contribution in improving yield of wheat varieties grown in Syria under water deficit conditions.

Materials and methods

Plant materials and growth conditions

Three durum wheat varieties viz., hourani (very old variety grown traditionally by farmers in southern part of Syria), sham3 (released in 1987) and douma3 (released in 2010) were used in this study to represent the germplasm grown in Syria for the last few decades. Seeds were obtained from the Crop Research Directorate, General Commission for Scientific Agricultural Research, Syria, and sown under rainfed conditions in the field on 20th Nov. 2011 in the 1st settlement zone (Jellen Research Station, annual rainfall 400mm) and the 2nd settlement zone (Izra Research Station, annual rainfall 291mm). The soil in both zones was clay loamy. Crops were sown at an adjusted rate of 300 viable seeds/m² (seeds were sown in rows, each variety in 6 rows, each row was 4 meter long, distance between rows was 20 cm) in a completely randomized block design with three replications. Normal agronomic practices were performed and relevant metrological parameters were obtained from the observatory at each research station including daily minimum and maximum temperature and rainfall. Chlorophyll content (Chl), membrane stability index (MSI), relative water content (RWC), chlorophyll fluorescence $Fv/Fm$ were estimated on the first fully expanded leaf (third from top) at the vegetative stage and the flag leaf at anthesis and post anthesis stage.

Chlorophyll content estimation

Total chlorophyll content was estimated in intact flag leaves using a portable chlorophyll meter (CCM-200, Opti-Sciences, England). The meter makes instantaneous and non-destructive readings on a plant based on the quantification of light intensity (peak wavelength: approximately 650 nm: red LED) absorbed by the tissue sample. A second peak (peak wavelength: approximately 940
nm: infrared LED) is emitted simultaneously with red LED to compensate the leaf thickness.

**Membrane stability index**
Membrane stability index was determined by recording the electrical conductivity of leaf leachates in distilled water at 40 and 100 °C (Deshmukh et al., 1991). Leaf samples (0.1 g) were cut into discs of uniform size and taken in test tubes containing 10 ml of distilled water in two sets. One set was kept at 40 °C for 30 min, and the other set at 100 °C in boiling water bath for 15 min and their respective electric conductivities were measured by Conductivity meter.

**Relative water content**
Relative water content (RWC) was determined by the method described by Barrs and Weatherly (1962). Hundred mg leaf material was taken and kept in distilled water in a petri-dish for 2 h to make the leaf tissue turgid. The turgid weights of the leaf materials were taken after carefully soaking the tissues between the two filter papers. Subsequently, this leaf material was kept in a butter paper bag and dried in oven at 65 °C for 24 h and their dry weights were recorded and RWC was calculated as follow:

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RWC = \frac{(FW-DW)}{(TW-DW)} \times 100
\]

Where:
FW: leaf fresh weight, DW: leaf dry weight, TW: leaf turgid weight

**Chlorophyll fluorescence**
Estimation of the polyphasic rise of fluorescence transients of intact leaves of non-stressed and water stressed plants was measured by a Plant Efficiency Analyzer (PEA, Handsatech Instruments Ltd., King’s Lynn, UK) according to Strasser et al. (1995).

**Yield and yield components**
On mid June, plants harvested from a one-meter square area were used for recording the biological and grain yield, number of tillers/m², number of grain/ear and 1000 grain weight.

**Statistical analysis**
Data were analyzed statistically and analysis of variance (ANOVA) for factorial design at each growing zone was worked out using CoStat6.311 Cohort software and LSD values were determined at \( P < 0.05 \). Standard error (SE) was also calculated and presented as vertical bars.

**Results and discussion**
Our findings indicated that all varieties grown in the 1st zone were more superior compared with those in the 2nd zone. However, modern variety (douma3) was more superior and showed higher values of the tested parameters compared with old (hourani) and intermediate (sham3) varieties. The total amount of the rainfall in the 2nd zone was 19% less than that in the 1st zone i.e., 292.9 mm and 358.8mm, respectively (Fig. 1). Terminal drought stress was experienced by the varieties in both zones, however the drought was more severe in case of the 2nd settlement zone. Data on membrane stability index showed that douma3 was more superior at post anthesis stage in the 1st zone and no significant differences were recorded between the three varieties at anthesis stage. In the 2nd zone, douma3 showed higher values 78.3, 75.9
and 65.6% at all growth stages namely at vegetative, anthesis and post anthesis stages, respectively (Fig. 2a and b). Membrane stability index increased by 7 and 14% in modern variety douma3 compared with hourani at vegetative and post anthesis stages, respectively in the 1st settlement zone while in the 2nd zone douma3 was superior compared to hourani by 20, 7 and 7% at vegetative, anthesis and post anthesis, respectively. This character was used successfully by many wheat breeders for evaluating drought stress tolerance and it’s association with drought tolerance and yield stability under water stress conditions (Almeselmani et al., 2012). Higher membrane stability which meant that cells were protected much better and maintained higher water content which is essential for all physiological activities. Microscopic investigations of dehydrated cells, revealed damages including cleavage in the membrane and sedimentation of cytoplasm content (Blackman et al., 1995). Probably, in these conditions, ability to osmotic adjustment is reduced (Meyer and Boyer, 1981).

Significant differences in relative water content were recorded between all varieties in both zones (Fig. 3a and b); however, hourani showed the lowest values in both zones at all growth stages. The relative water content showed no significance between intermediate (sham3) and modern (douma3) varieties at vegetative and anthesis stage in the 1st zone. In the 2nd zone douma3 was more superior at all growth stages, particularly at anthesis stage. Major differences between douma3 and hourani were recorded at post anthesis stage i.e., 9% in the 1st zone and 6% in the 2nd zone, re-

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![Membrane stability index (%)](image)

**Fig. 1** Total amount of rainfall (mm) in the 1st and 2nd settlement zone during the growing season Oct/2011 up to June/2011.

![Membrane stability index (%)](image)

**Figs. 2a and b** Membrane stability index (%) of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st (a) and 2nd (b) settlement zones at vegetative, and anthesis and post anthesis stages, LSD values at $P < 0.05$ in the 1st zone: 0.9 and 2nd zone:1.5 respectively, vertical bars indicate SE.
spectively. According to Almeselmani et al. (2011) RWC indicates the water status of the cells and has significant association with yield and stress tolerance. The differences in RWC in wheat leaves may also be due to differences in the ability of the tested varieties to accumulate and adjust osmotically to maintain tissue turgor and hence physiological activities. According to Shamsi (2010) difference in RWC of cultivars that are under drought stress may be due to differences in their ability to absorb more water from soil or ability of stomata to reduce water loss. It is also reported that high relative water content is a resistant mechanism to drought, and is the result of more osmotic regulation or less elasticity of tissue cell wall (Ritchie et al., 1990). It is defined that decrease of relative water content close stomata and also, after locking of stomata, will reduce photosynthesis rate (Cornic, 2000).

The variety sham3 had attained the highest values for chlorophyll content at all growth stages in the 1st zone i.e., 63.3, 53.8 and 53.3, respectively, while in the 2nd zone, douma3 was more superior at all growth stages i.e., 52.2, 49.8 and 48.2, respectively. Chlorophyll content of all varieties was high at the vegetative stage in both zones, and then decreased at the anthesis and post anthesis stages, the differences between varieties were highly significant in the 2nd zone compared with the 1st zone. The new variety douma3 had higher chlorophyll content than hourani at all growth stages by 14, 16 and 18%, respectively in the 2nd zone (Fig. 4a and b). Chlorophyll is one of the major chloroplast components for photosynthesis and relative chlorophyll content has a positive re-

![Relative water content (%)](image1)

![Relative water content (%)](image2)

Figs. 3a and b Relative water content (%) of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st (a) and 2nd (b) settlement zones at vegetative, and anthesis and post anthesis stages, LSD values at P<0.05 in the 1st zone: 1.4 and 2nd zone: 1.8 respectively, vertical bars indicate SE.

The relationship with photosynthetic rate and flag leaf chlorophyll content is an indicator of the photosynthetic activity and its stability for the conjugation of assimilate biosynthesis (Bijanzadeh and Emam, 2010). Chlorophyll concentration has been used as an index for evaluation of photosynthetic rate (Herzog, 1986). Higher chlorophyll content is essential for providing assimilates for grain particularly during the produ-
According to Nageswara et al. (2001) and Wright et al. (1994) chlorophyll content of leaf is an indicator of photosynthetic capability of plant tissues. Our recorded data on chlorophyll fluorescence showed that douma3 was the superior variety in both zones at all growth stages. Hourani showed the lowest values at anthesis and post anthesis stages in the 1st zone i.e., 0.67 and 0.64, respectively. In the 2nd zone, the lowest values at all growth stages were recorded by hourani. Douma3 was superior over hourani by 12, 16 and 10% at vegetative, anthesis and post anthesis stages, respectively in the 2nd zone (Figs. 5a and b). In the assessment of effects caused by high temperature or water deficit on the photosynthetic activity, chlorophyll fluorescence may be a safer indicator than net photosynthetic rate, because it is a practical and precise method (Costa et al., 2003). Chlorophyll fluorescence analysis is a sensitive in-
Fig. 6 Biological yield (g/m²) of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st and 2nd settlement zones, LSD value at \( P \leq 0.05 = 38 \), vertical bars indicate SE.

Fig. 7 Grain yield (g/m²) of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st and 2nd settlement zones, LSD value at \( P \leq 0.05 = 17 \), vertical bars indicate SE.

dicator of tolerance of the photosynthetic apparatus to environmental stress (Maxwell and Johnson, 2000). Higher chlorophyll fluorescence of the modern varieties showed better photosynthetic activities and the healthy status of the photosystem II during water shortage. The \( F_v/F_m \) ratio characterizes the maximum yield of the primary photochemical reaction in dark-adapted leaves and is frequently used as a measure of the maximal photochemical efficiency of PSII (Krause and Weis, 1991).

The analyses of variance for yield components and related traits revealed that all decreased in the 2nd zone compared with the 1st zone. Douma3 showed the highest values for biological yield in both zones. The lowest biological yields were recorded in both zones by sham3 i.e., 1239 and 764 g/m², respectively (Fig. 6). In general more grain yield was achieved in the modern variety douma3 which maintained the highest grain yield in the 1st and 2nd zones i.e., 582 and 437 g/m², respectively. Douma3 was superior in grain yield compared to hourani and sham3 by 59 and 4%, respectively in the 1st zone and by 25 and 10%, respectively in the 2nd zone (Fig. 7).

The number of tillers/m² and the number of grains/ear were greater in the 1st zone than in the 2nd zone. On average, modern (douma3) and intermediate (sham3) varieties had more tillers/m² and more number of grain /ear compared to old variety (hourani). The highest number of tillers/m² was recorded by douma3 in both zones i.e., 318 and 217, respectively (Fig. 8). Recorded data showed no significant differences in the number of grain/ear between hourani and sham3 in the 1st zone, while douma3 showed the highest values in both zones i.e., 51.4 and 38.7, respectively. The number of grain/ear increased from old (hourani) to modern (douma3) germplasm by 8% and 19% in 1st and 2nd zone, respectively. Number of grain/ear increased from intermediate (sham3) to modern (douma3) germplasm by 7% and 15% in
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Fig. 8 Tiller number/m² of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st and 2nd settlement zones, LSD value at $P \leq 0.05 = 32$, vertical bars indicate SE.

Fig. 9 Number of grain/ear of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st and 2nd settlement zones, LSD value at $P \leq 0.05 = 1.08$, vertical bars indicate SE.

Fig. 10 1000 grain weight (g) of old (hourani), intermediate (sham3) and modern (douma3) wheat varieties in 1st and 2nd settlement zones, LSD value at $P \leq 0.05 = 1.3$, vertical bars indicate SE.

It is obvious that modern variety douma3 was superior in all physiological traits, yield and yield components. Higher yield in modern (douma3) variety could be a reflection of better physiological performance of this variety under rainfed conditions. Therefore, future breeding programs in modern wheat varieties should necessarily study the physiological traits of the varieties under test as an indicator of yield potential.

References


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