

Physiological Attributes Associated to Water Deficit Tolerance of Syrian Durum Wheat Varieties

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Abstract

The demand for wheat will increase over the next 20 years with global demand for wheat as food for human consumption. Drought is one of the most important factors to limit wheat productivity in the world, especially in dry and semidry areas where large fluctuation in the amount and distribution of the rain these areas faces. Some plants have a set of physiological adaptations that allow them to tolerate water stress and the degree of adaptations may vary considerably among species. The current study was conducted with some drought tolerant and susceptible durum wheat varieties to examine the physiological response under drought stress imposed by planting wheat varieties under rainfed condition in the 1st and 2nd settlement zone in southern part of Syria and to identify the most suitable criteria for screening wheat variety for drought tolerance. Our results showed significant reduction in all physiological characters (membrane stability index, Relative water content, chlorophyll content and chlorophyll fluorescence) in all varieties grown in the 2nd zone compared to the 1st one. More reduction in all physiological traits, yield and yield component were recorded in the drought susceptible varieties compared to other varieties. Association between all these character and yield components was observed particularly at anthesis stage. It is clear that all these parameters could explain some of the mechanisms which indicate tolerance to drought and help in understanding the physiological responses that enable plants to adapt to water deficit and maintain growth and productivity during stress period and indicate important of these traits in breeding programs for screening and selection of tolerant varieties.

Keywords: Water deficit; rainfed; wheat; chlorophyll; membrane stability; relative water content; *Fv/Fm*

Abbreviations: RWC— relative water content; MSI—membrane stability index; *Fv/Fm*—chlorophyll florescence; 1st zone— first settlement zone; 2nd zone—Second settlement zone

1. Introduction

Drought limits plant growth and field crops production more than any other environmental stresses (Zhu, 2002; Kirigwi et al., 2004; Zheng et al., 2010; Almeselmani et al., 2011). Its remains an ever-growing problem that severely limits crop production worldwide and causes important agricultural losses particularly in arid and semiarid areas (Boyer et al., 1982). Almost 32 % of wheat crops face

various types of drought stress during the growth season in developing Countries (Morris et al, 1991). Wheat is an important food for more than 35% of world population and it is the major source of calories (Kazemi, 2009). A recent increase in the world wheat production is not sufficient to meet the demands of a growing population and wheat production in many regions of the world is below average because of adverse environmental conditions and wheat cultivation is mainly restricted to such zones with scarcity of water (Moaveni, 2011). Drought affected wheat productivity throughout the world and particularly in arid, semi-arid and Mediterranean climates due to the unpredictable and erratic rainfall in these regions (Jones and Bradley, 1992).

It induces many physiological, biochemical and molecular response on plants; so that plants are able to develop tolerance mechanisms which will provide to be adapted to limited environmental conditions (Arora et al., 2002; Bohnert et al., 2006; Shinozaki and Yamaguchi-Shinozaki, 2007; Gholamin et al., 2010). Moderate to severe water stress drastically affects various morpho-physiological traits in wheat such as chlorophyll fluorescence, water use efficiency and dry matter yield (Ehdaie et al., 1991). Since genotypic differences for these traits have been reported for various crop species including wheat, these traits have been used to identify drought tolerant genotypes in various crops. According to the previous studies, there is a link between various physiological responses of crop plants to drought and their tolerance mechanisms such as high relative water content and water potential (Clarke and McCaig, 1982; Ritches et al., 1990; Keyvan, 2010; Datta et al., 2011) membrane stability (Kaur et al., 1988; Sairam et al., 1990; Gholamin and Khayatnezhad, 2010) and pigment content stability under stress (Sairam et al., 1990; Sairam et al., 1998; Ghobadi et al., 2011). Dark-adapted values of F_v/F_m reflect the potential quantum efficiency of PSII and are used as a sensitive indicator of photosynthetic performance, with optimal values of around 0.832 measured from most plant species (Johnson et al., 1993; Bogale et al., 2011).

Water stress issues are increasing in wheat breeding programs, the choice of parents is the most important step in the development of varieties adapted to water-stress conditions and breeding and selection for high yield under drought has been an important objective of crop breeders working in these environments (El-Maghraby et al., 2005). Therefore achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards et al., 2002). Because of increasing drought damages on crops especially in Syria where arid and semi-arid climate predominates, it is essential to detect varieties that are well adapted to water shortage and to determine effective and reliable selection criteria for selecting drought tolerant varieties. The purpose of this research is to study the effect of drought stress on some physiological processes of tolerant and susceptible durum wheat varieties and to determine the best physiological criteria which can be used to discriminate tolerant wheat varieties at particular growth stage.

2. Materials and Methods

2.1 Plant Materials and Growth Conditions

Drought tolerant and susceptible durum wheat varieties were chosen in this study, viz., Sham5 and Doma3 (drought tolerant), Bohouth11 and Sham9 (moderately drought tolerant), Bohouth5 and Sham7 (drought susceptible) were used in this study. Seeds were obtained from Crop Research Directorate, GCSAR, and sown under rainfed conditions in the field on 20th Nov. 2010 in the second settlement zone (Izra research station, annual rainfall 299mm) and in the first settlement zone (Jellen agricultural research center, annual rainfall 400mm). Crops were sown at an adjusted rate of 300 viable seeds/m² in three replications. Normal agronomic practices were performed and relevant metrological parameters were obtained from the observatory at each research station and daily minimum and maximum temperature and rainfall were recorded. Chlorophyll content (chl), membrane stability index

(MSI), relative water content (RWC), chlorophyll fluorescence F_v/F_m were estimated on the first fully expanded leaf (third from top) at vegetative stage and flag leaf at anthesis stage.

2.2 Chlorophyll Content

The chlorophyll meter (SPAD meter) was used to measure the greenness or the relative chlorophyll concentration of leaves. 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 for to compensate the thickness leaf.

2.3 Membrane Stability Index

A conductivity test was done to estimate drought tolerance as suggested by Almeselmani et al., (2006). 100 mg leaf sample was placed in a test tube containing 10 ml of double distilled deionized water. Electrical conductivity of the solution was measured after incubating the test tubes at 45 °C and 100 °C.

2.4 Relative Water Content

Barrs and Weatherly, (1962) methods were used to determine relative water content. 100 mg leaf material was taken and kept in double distilled water in a petridish for two hours to make the leaf tissue turgid. The turgid weight, dry weight of the leaf materials was measured and RWC was calculated.

2.5 Chlorophyll Fluorescence

For the measurement of the chlorophyll fluorescence all the samples were covered with clips, kept in dark for 30 minutes before fluorescence measurements. The transients were induced by red light of 3000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ provided by an array of six light emitting diodes (peak 650 nm), which focused on the sample surface to give homogenous illumination over exposed area of sample surface and maximal quantum yield of PS II (F_v/F_m) was measured. Plant Efficiency Analyzer (PEA, Hansatech Instruments Ltd., King's Lynn, UK) were used according to Strasser *et al.*, (1995).

2.6 Yield and Its Components

Plants harvested at maturity and number of tillers, grain number per ear, 1000 grain weight, total biomass and grain yield/ m^2 were recorded.

The experiment was laid out in a completely randomized block design with three replications. The data were analyzed statistically by analysis of variance (ANOVA) and least significant differences (LSD) values were calculated. Correlation coefficient (r) between various physiological traits and yield components in wheat varieties in the 1st and 2nd zone at different growth stages were also calculated.

3. Results and Discussion

Reduced plant productivity due to drought is a major concern for wheat grown in arid and semiarid areas and development of high yielding wheat cultivars is a major objective in breeding programs (Kahrizi et al., 2010). Physiological understanding has resulted in more precise targeting of genetic variation and has resulted in higher yielding or more productive germplasm or varieties. This study allowed the understanding of the main physiological characters associated with yield potential, and identifying of suitable plant selection criteria, associated with yield increments.

Rainfall was well distributed up to anthesis stage, indicated that enough water was available for fast and rapid emergence of seeds (10-13 days after sowing). The total amount of rain received in the 1st

settlement zone were 388mm, at the same time, only 328mm were received in the 2nd settlement zone. However only 48mm were received in the 2nd zone at anthesis and grain filling stage, while 140mm in the 1st zone at the same period. In general these amount is not enough for ideal growth and yield in both zones for all varieties but the impact of water deficit stress imposed during anthesis and grain filling stage could be more sever for drought susceptible and moderately tolerant varieties particularly in the 2nd zone, the total amount of rainfall were received in this area during the growing season is shown in table (1).

Table 1. Total amount of rainfall (mm) per month during the growing season in 1st and 2nd settlement zone

Month	Rainfall mm	
	1 st zone	2 nd zone
Oct-10	1	3
Nov-10		
Dec-10	85	91
Jan-11	44.5	55
Feb-11	109.5	93
Mar-11	60.5	38
Apr-11	61.5	16
May-11	26	32
Jun-11		
Total amount of rainfall	388	328

3.1 Effect of Water Deficit on Membrane Stability Index

Cell membrane is one of the first targets of many plant stresses (Levitt, 1972) and it is generally accepted that maintenance of their integrity and stability under water deficit conditions is major component of drought tolerance in plants (Bajji et al., 2001). According to Blum et al., (2001) and Thiaw and Hall, (2004) selection for slow leaf electrolyte leakage under heat stress has been proposed as a method for increasing heat tolerance and heat resistance of several crops by enhancing membrane thermo-stability. Membrane stability is a widely used criterion to assess crop drought tolerance, since water stress caused water loss from plant tissues which seriously impairs both membrane structure and function (Buchanan et al., 2000).

Our results indicated significant differences in MSI between all wheat varieties at vegetative stage in both zones; however, the differences were highly significant in the 2nd zone compared to 1st one and MSI values were higher in the 1st zone compared to the 2nd one. Drought susceptible variety Bohouth5 showed highest MSI value i.e., 85.3% at vegetative stage in the 1st zone, while drought tolerant variety Sham5 showed highest value in the 2nd one i.e., 83.1% as shown in (fig 1a). No significant differences were recorded between Sham7, Bohouth11, Sham9 and Douma3 in the 1st zone and the differences between these varieties were not highly significant in the 2nd zone. Drought tolerant varieties Douma3 and Sham5 showed highest MSI values at anthesis stage i.e., 78.3 and 78.6% in the 1st zone and 74.9 and 77.6% in the 2nd zone respectively as observed in (fig 1b). However MSI values in the 1st zone at this stage were higher compared to the second one and our recorded data showed that MSI values at this stage were much lower compared to vegetative one in all varieties. The results from electrolyte leakage measurements in our experiment showed that membrane integrity was conserved for tolerant compared to susceptible varieties, this is in agreement with the conclusion of Martin et al., (1987); Vasquez Tello et al., (1990) and Almeselmani et al., (2011) that electrolyte leakage was correlated with drought tolerance. The leakage was due to damage to cell membranes which become more permeable (Senaratna and Kersie, 1983). This shows the importance of this test in discriminating among tolerant and susceptible varieties.

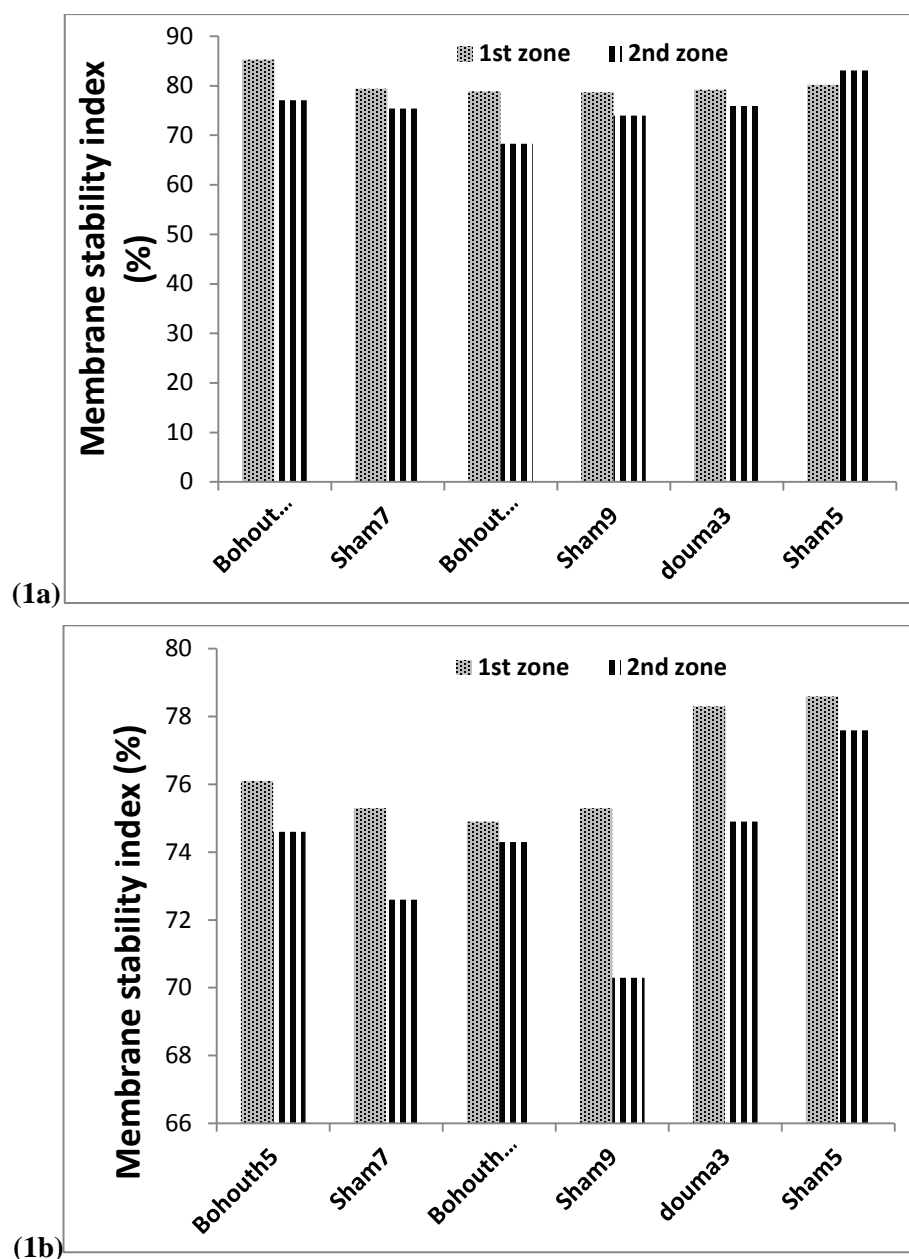


Fig (1a, 1b). Membrane stability index (%) of tolerant, moderately tolerant and susceptible wheat varieties at vegetative (a) and anthesis stage (b) grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 1.2; Location= 2.6; Stages= 2.8

3.2 Effect of Water Deficit on Relative Water Content

RWC indicate the water status of the cells and have significant association with yield and stress tolerance (Almeselmani et al., 2006; 2011). RWC of the leaves is very responsive to drought stress and has been shown to correlate with drought tolerance (Colom and Vazzana, 2003) and RWC of the leaves has been proposed as a better indicator of water stress than other growth or biochemical parameters of the plants (Sinclair and Ludlow, 1985).

Significant differences in RWC was observed between the varieties at various stages and our results showed that all varieties maintained higher RWC at vegetative compared to anthesis stage in both zones and more RWC were recorded in the 1st compared to the 2nd zone in all varieties. Data recorded

in (fig 2a) showed that moderately drought tolerant and drought tolerant varieties Sham9 and Douma3 had highest RWC values at vegetative stage in the 1st zone i.e., 91.8 and 90.3% respectively, while drought tolerant variety Sham5 showed highest value at anthesis stage as recorded in (fig 2b). In the 2nd settlement zone drought tolerant variety Douma3 and Sham5 showed highest RWC values at vegetative and anthesis stage i.e., 88 and 87.9% respectively.

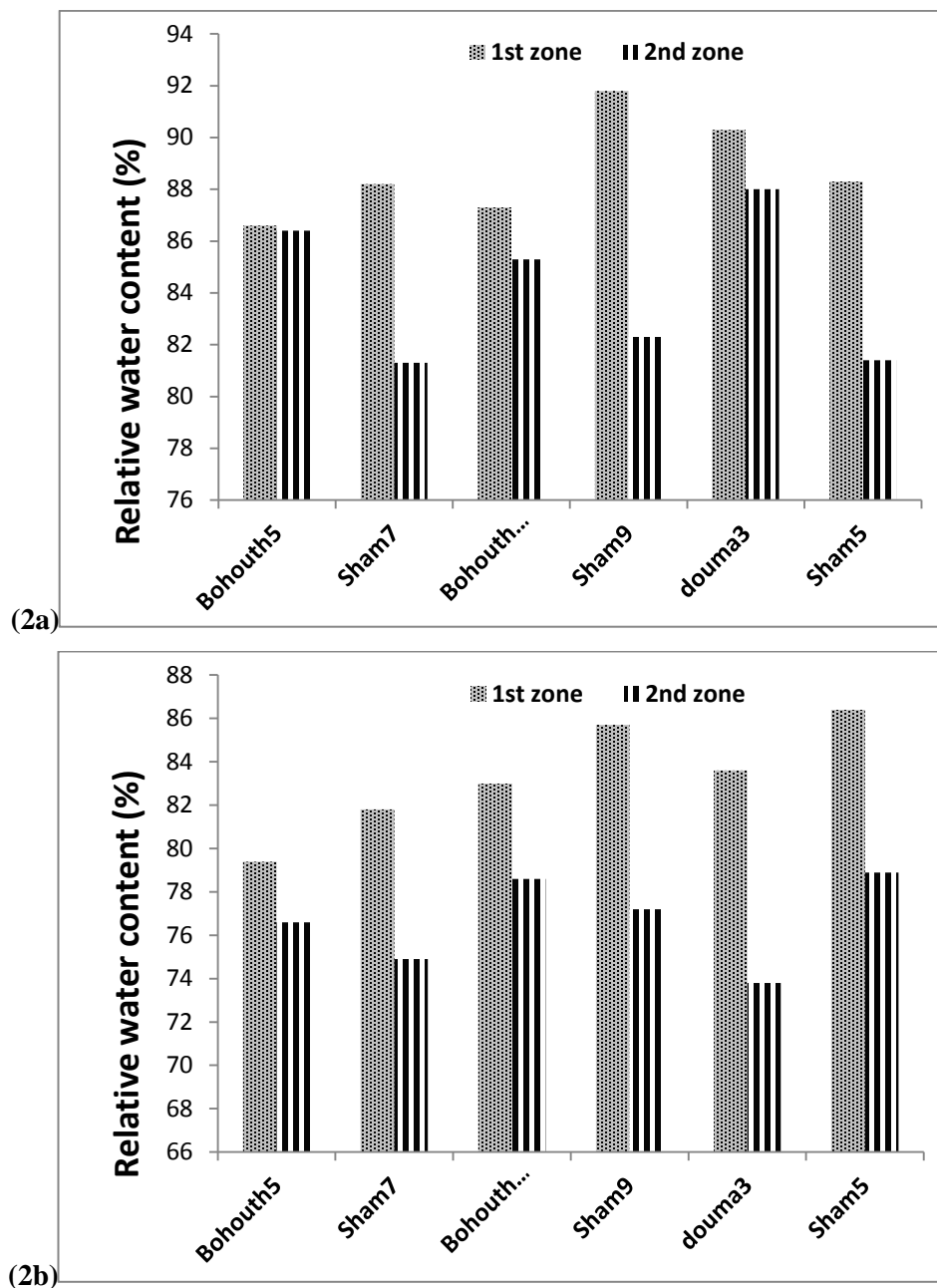


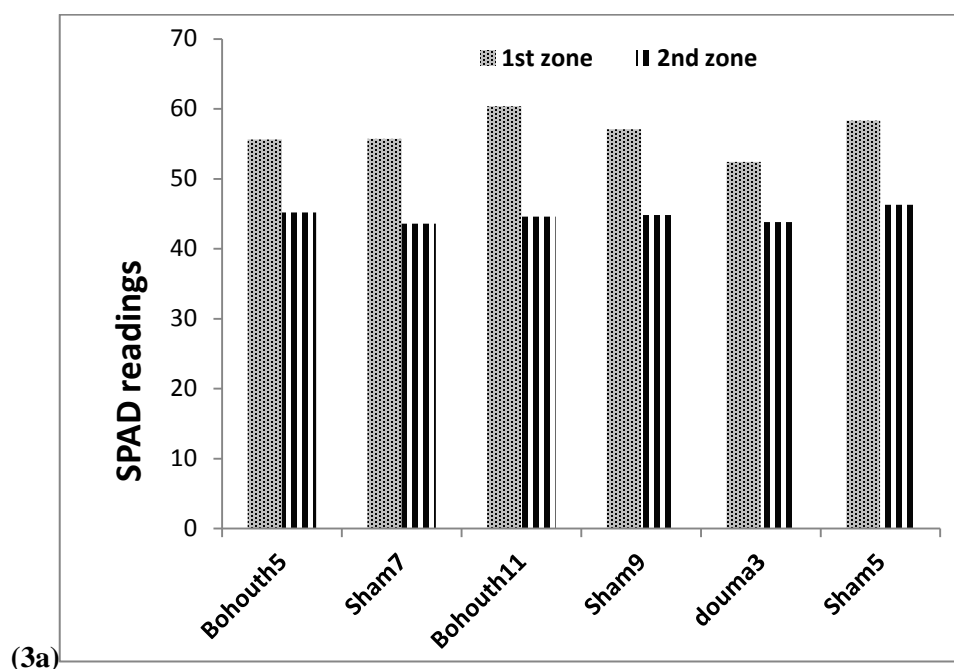
Fig (2a, 2b). Relative water content (%) of tolerant, moderately tolerant and susceptible wheat varieties at vegetative (a) and anthesis stage (b) grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 2.2; Location= 3.6; Stages= 2.4

This deviation in RWC between varieties may be attributed to differences in the ability of the varieties to absorb more water from the soil and or the ability to control water loss through the stomata's. It 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 Keyvan, (2010) difference in

RWC of cultivars that are under drought stress may be due differences in their ability of absorption more water from soil or ability of stomata to reduce the loss of water. Tatar and Gevrek (2008) and Kameli and Losel (1996) showed that wheat dry mater production, RWC decreased under drought stress condition. Siddiqe et al. (2000) reported that there was a positive relation between RWC and photosynthetic rate and among several methods used to characteristics internal plant water status and is an integrative indicator (Parsons and Kowe, 1984) and was used successfully to identify drought resistant cultivars (Matin et al., 1989). It is reported that high relative water content is a resistant mechanism to drought, and that high RWC is the result of more osmotic regulation or less elasticity of tissue cell wall (Ritchie et al, 1990). The RWC is usually higher in plants, which are adapted to dry conditions, and similar observations had earlier been recorded by Carter and Paterson (1985).

3.3 Effect of Water Deficit on Chlorophyll Content

Chlorophyll loss is associated to environmental stress and the variation in total chlorophyll/carotenoids ratio may be a good indicator of stress in plants (Hendry and Price, 1993). Chlorophyll concentration has been known as an index for evaluation of source (Herzog, 1986), therefore decrease of chlorophyll can be considered as a non-stomata limiting factor under drought stress conditions. Our data recorded at vegetative and anthesis stage, showed that chlorophyll content increased as plant advance in age in 1st settlement zone, while no such trend observed in the 2nd zone. In general significant difference was recorded between all varieties in both zones. However varieties grown in the 1st zone maintained higher chlorophyll content compared to the 2nd zone. Drought moderately tolerant variety Bohouth11 showed highest chlorophyll content at vegetative and anthesis stages in the 1st zone i.e., 60.4 and 63.9 respectively as shown in (fig3 a and b), while in the 2nd zone drought tolerant variety Sham5 maintained highest chlorophyll content at both stages i.e., 46.3. This is supported by the findings of Sikuku et al. (2010) noting the inhibition of chlorophyll synthesis and inability of sensitive wheat to withstand water deficit. High chlorophyll content is a desirable characteristic because it indicates a low degree of photoinhibition of photosynthetic apparatus, therefore reducing carbohydrate losses for grain growth (Farquhar et al., 1989). According to Ityrbic et al., (1998) water stress condition caused reduction in chlorophyll content. These findings are in agreement with Araus et al., (1998) who reported that drought treatment caused a 20% reduction in leaf chlorophyll content.



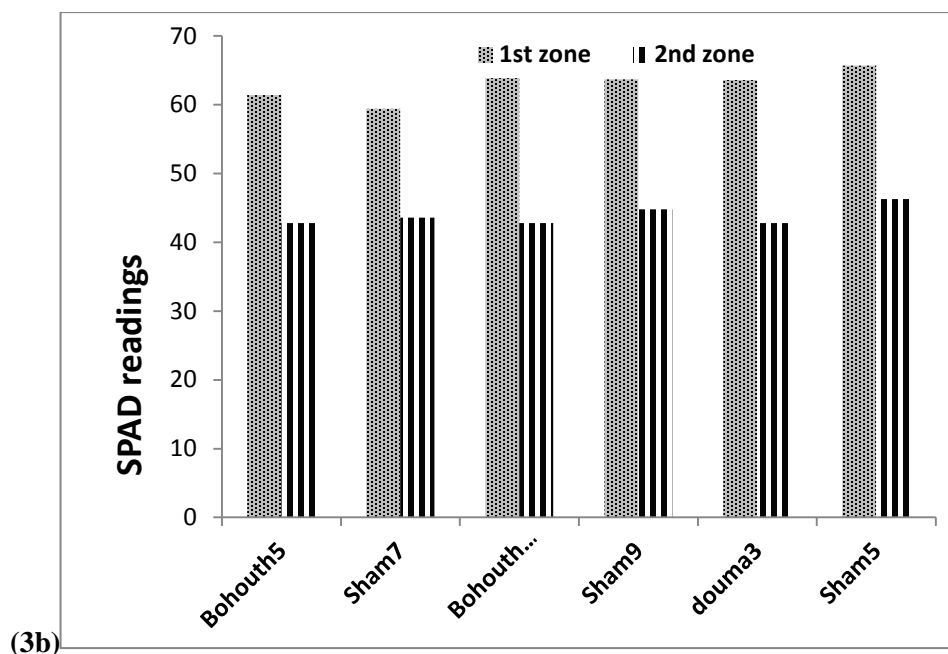


Fig (3a, 3b). Chlorophyll content (SADP reading) of tolerant, moderately tolerant and susceptible wheat varieties at vegetative (a) and anthesis stage (b) grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 2.3; Location= 1.3; Stages= 1.6

There are reports about decrease of chlorophyll in the drought stress conditions (Mayoral et al, 1981; Kuroda et al, 1990; Almeselmani et al., 2011). Also, it is reported that chlorophyll content of resistant and sensitive cultivars reduced in response to drought and thermal stress. But resistant cultivar to drought and thermal stress conditions had high chlorophyll content (Sairam et al., 1997). Chlorophyll maintenance is essential for photosynthesis under drought stress and higher chlorophyll content and lower percent of reduction under stress in tolerant genotype of wheat has also been reported (Kraus et al., 1995; Sairam et al., 1997; Nyachiro et al., 2001). According to Manivannan et al., (2007) chlorophyll is one of the major chloroplast components for photosynthesis and relative chlorophyll content has a positive 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 (Bijanazadeh and Emam, 2010). This trait has been used successfully by many workers for screening and selection for drought tolerance wheat cultivars (Almeselmani et al., 2011). Finally the assessment of photosynthetic pigments and consequently their relationships is an important indicator of senescence (Brown et al., 1991).

3.4 Effect of Water Deficit on Chlorophyll Fluorescence

Use of a chlorophyll fluorescence technique as a tool to investigate drought tolerance in different wheat genotypes has been reported (Almeselmani et al., 2011) and chlorophyll fluorescence analysis is a sensitive indicator of tolerance of the photosynthetic apparatus to environmental stress (Maxwell and Johnson, 2000). 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 photosynthesis rate, because it is a practical and precise method (Yamane et al., 1997; Costa et al., 2003). Our findings indicated that highest chlorophyll fluorescence in both zones and at different stages were recorded in drought tolerant variety Sham5, however the F_v/F_m values were higher at vegetative stages in both zones and the values in the 1st zone were more higher compared to the 2nd zone as shown in (fig 4a). Lowest F_v/F_m values at anthesis stage were recorded in drought susceptible varieties Bohouth5 in 1st zone and Sham7 in the 2nd zone i.e., 0.74 and 0.63 respectively as observed by (fig 4b). The F_v/F_m ratio, which characterizes the maximum yield of the primary photochemical reaction in dark-adapted

leaves and frequently used as a measure of the maximal photochemical efficiency of PSII, was reduced under water deficit condition. The patterns of changes in fluorescence parameters observed in this study are supported by the pattern of change reported by many authors under drought conditions (Long et al., 1994; Aruas et al., 1998; Zlatev and Yordanov, 2004).

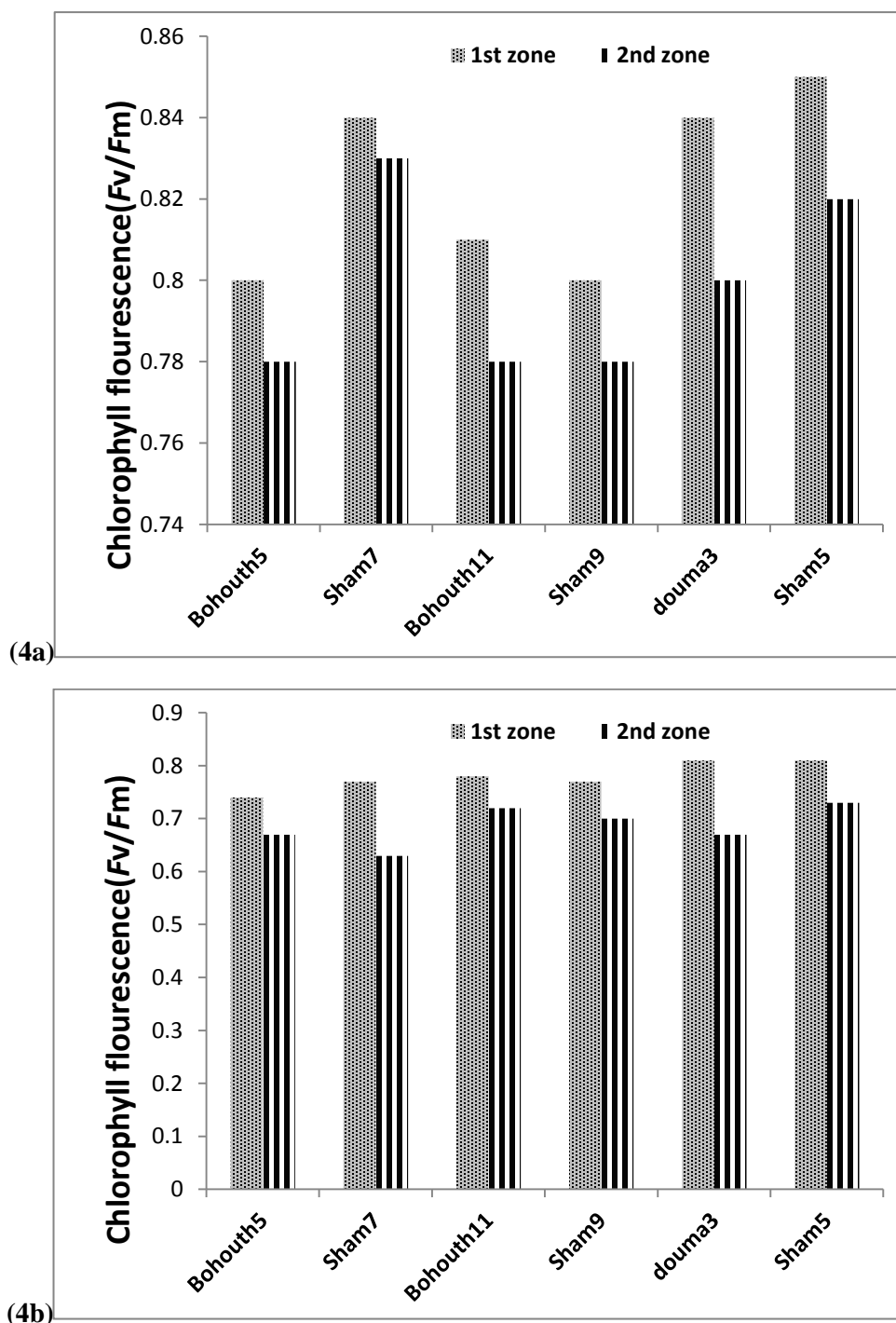


Fig (4a, 4b). Chlorophyll fluorescence (Fv/Fm) of tolerant, moderately tolerant and susceptible wheat varieties at vegetative (a) and anthesis stage (b) grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 0.03; Location= 0.009; Stages= 0.02

It is known that all of the environmental constraints affected chlorophyll fluorescence parameters (Havaux, 1993; Schreiber et al., 1995). Under this stress usually a water deficit in plant tissues develops, thus leading to a significant inhibition of photosynthesis. The ability to maintain the functionality of the photosynthetic machinery under water stress, therefore, is of major importance in drought tolerance (Mohammadi et al., 2009), and the drastic changes in chlorophyll fluorescence measurement most probably indicates the physical dissociation of PSII reaction centers from light harvesting complex, a substantial accumulation of inactivated PSII centers as well as photoinhibition. Ma et al., (1995) reported that higher photochemical efficiency played important role in drought tolerance. This phenomenon is a criterion for thylakoid membrane integrity and electron transfer efficiency from photosystem II to photosystem I (Mamnoue, 2006). According to Mamnoue (2006) the photochemical efficiency of photosystem II is determined by the F_v/F_m ratio which is decreased significantly during drought stress.

Chlorophyll fluorescence analysis may provide a sensitive indicator of stress conditions in plants. It can also be used to estimate the activity of thermal energy dissipation in photosystem II, which protects photosynthesis from the adverse effects of light and heat stress. For this reason, chlorophyll fluorescence has often been proposed as a useful tool for screening durum and bread wheat for drought. Chlorophyll fluorescence has been used in several studies to detect the genotypic differences in response to drought in many plant species, including wheat. Flagella et al., (1995) and Almeselmani et al., 2011 also reported that drought tolerant cultivars showed a smaller decrease in photosynthetic efficiency (F_v/F_m ratios).

3.5 Effect of Water Deficit on Yield and Yield Components

Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao et al., 2009), and the worldwide losses in crop yield from water stress exceed the losses from all other classes combined (Kramer, 1980).

Our experiments showed significant differences in total plant biomass between the different varieties in both zones and drought susceptible wheat varieties Bohouth5 and Sham7 had the lowest total biomass i.e., 1186 and 1173g/m² in the 1st zone and 1047 and 1147 g/m² in the 2nd zone, while highest value was recorded in drought moderately tolerant variety Sham9 i.e., 1452 and 1417g/m² in the 1st and 2nd zone respectively as shown in (fig 5). According to Clarke et al., 1991 and Ashraf, 1998 plant produces their maximum biomass under adequate water supply, whereas moisture stress causes a marked decrease in plant biomass production.

The stress factors especially drought negatively affects plant growth and development and causes a sharp decrease of plants productivity (Pan et al., 2002). Blum and Pnuel (1990) reported that yield and yield components of twelve spring wheat varieties were significantly decreased when they received minimum annual precipitation. Significant differences in grain yield were recorded between the varieties under study in both zones and the differences were highly significant between different varieties in case of the 2nd zone. Highest grain yield value was recorded in the moderately drought tolerant variety Sham9 i.e., 653 g/m², followed by 641g/m² in drought tolerant variety Sham5 in the 1st zone as shown in (fig 6), while in the 2nd zone the highest value was recorded in drought tolerant variety Sham5 i.e., 639g/m², and the lowest value was recorded in drought susceptible variety Bohouth5 i.e., 483g/m². The negative effect of drought stress on yield and yield performance has been well documented as a major problem in many developing countries of the world (Guo et al., 2004; Passioura, 2007). Feil, (1992) reported that Selection for grain yield would have modified certain morphological and physiological traits which are linked to yielding ability.

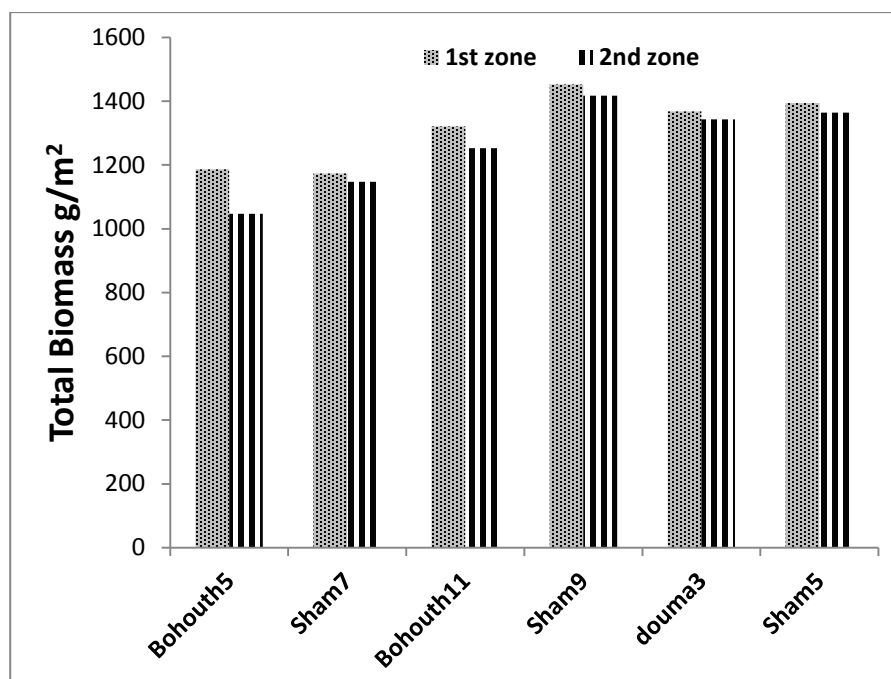


Fig (5). Total Biomass g/m² of tolerant, moderately tolerant and susceptible wheat varieties grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 32; Location= 41

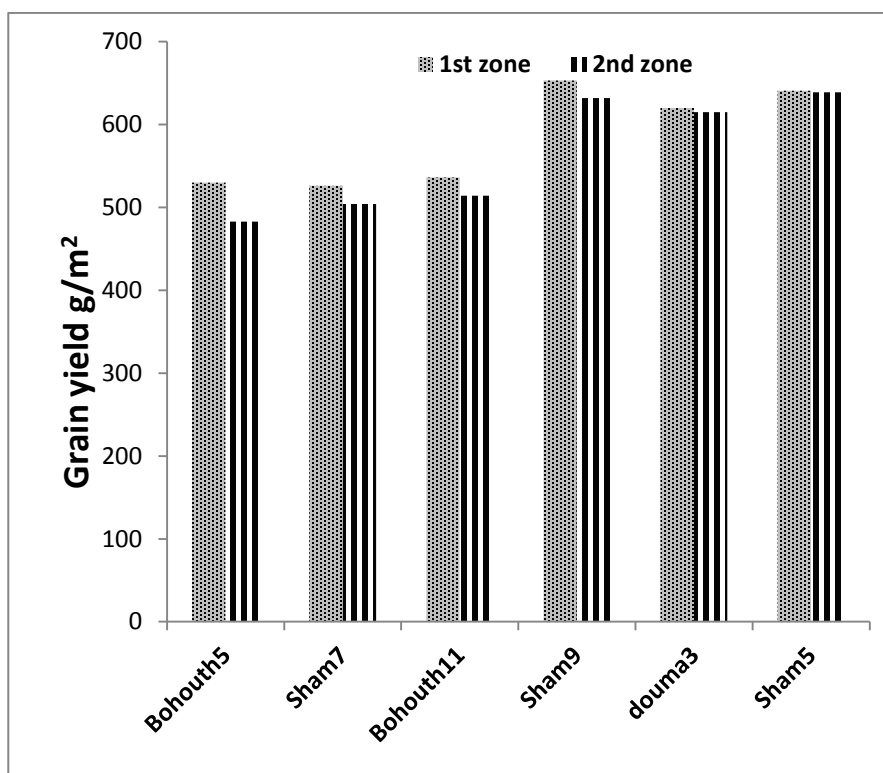


Fig (6). Grain yield g/m² of tolerant, moderately tolerant and susceptible wheat varieties grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 13; Location= 24

Data recorded in (fig 7) showed significant differences in tiller number/m² between the varieties in both zones, the highest tiller number/m² were recorded in drought moderately tolerant variety Sham9

and drought tolerant variety Sham5 in the 1st zone i.e., 408, while in the 2nd zone highest value were recorded in Sham5 i.e., 405. Grain number/ear decreased significantly in the 2nd zone compared by the 1st zone in all varieties. Highest grain number/ear in both zones were recorded in drought tolerant varieties Sham5 and Douma3 i.e., 52.3 and 51.8 in the 1st zone and 46.2 and 43.9 in the 2nd zone respectively as observed in (fig 8). 1000 grain weight also differ significantly between the varieties in both zones, however significant reduction in 1000 grain weight were recorded in all varieties in the 2nd zone compared to the 1st one, highest 1000 grain weight were recorded in drought susceptible variety Bohouth5 in the 1st zone and in drought moderately tolerant variety Bohouth11 in the 2nd zone as shown in (fig 9). Present investigation showed that number of grains per main spike, 1000-grain weight, number of tillers per plant, biological yield and grain yield per plant were decreased under stressed environment which is also reported by Chandler and Singh (2008) and Almeselmani et al., (2011). Drought stress may reduce all yield components, particularly the number of fertile spikes per unit area and the number of grains per spike (Giunta et al., 1993; Simane et al., 1993), while kernel weight is negatively influenced by high temperatures and drought during ripening (Atefeh et al., 2011). Drought stress reduced the number of grain/spike and grain yield (Saleem, 2003) and the genotypes with higher number of grain/ear produce more yields (Iqbal et al., 1999). According to Elhafid et al., (1998) drought leads to reducing inoculation of flower and this affects number of produced grain. Caldrini et al., (1999) believed that increasing of grain yield in recent years is primarily indebted of increasing of number of grain per spike and this component of yield is more important than grain weight, although both factors cause limitation of yield. Significant reduction in 1000-grain weight of wheat has also been reported by Ahmed and Arian (1999) while Akram et al., 2010 reported differential response of varieties towards grain weight.

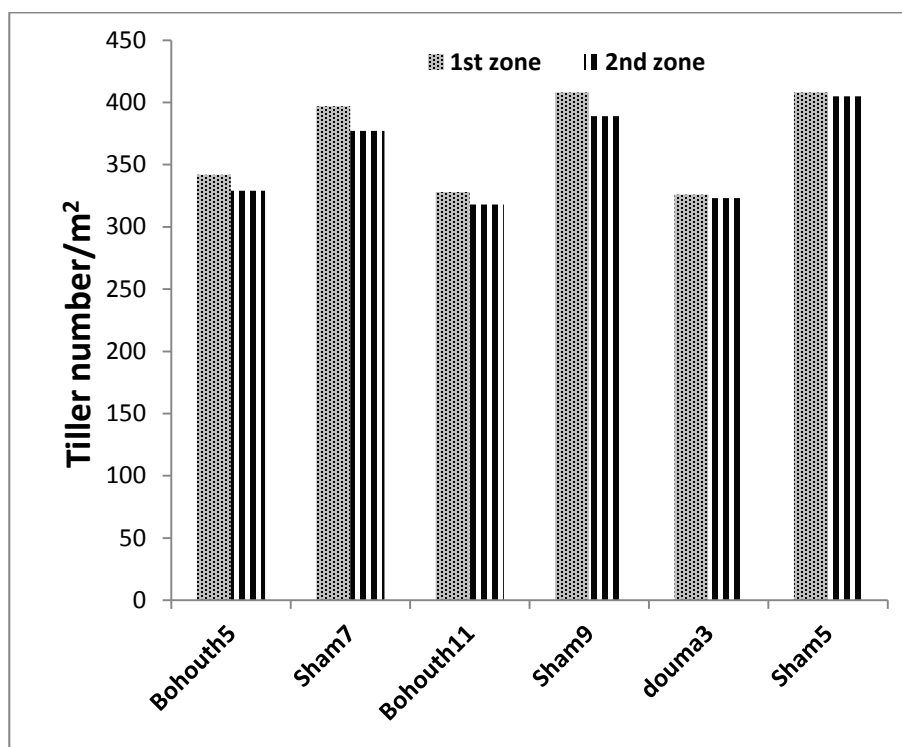


Fig (7). Tiller number/m² of tolerant, moderately tolerant and susceptible wheat varieties grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 21; Location= 32

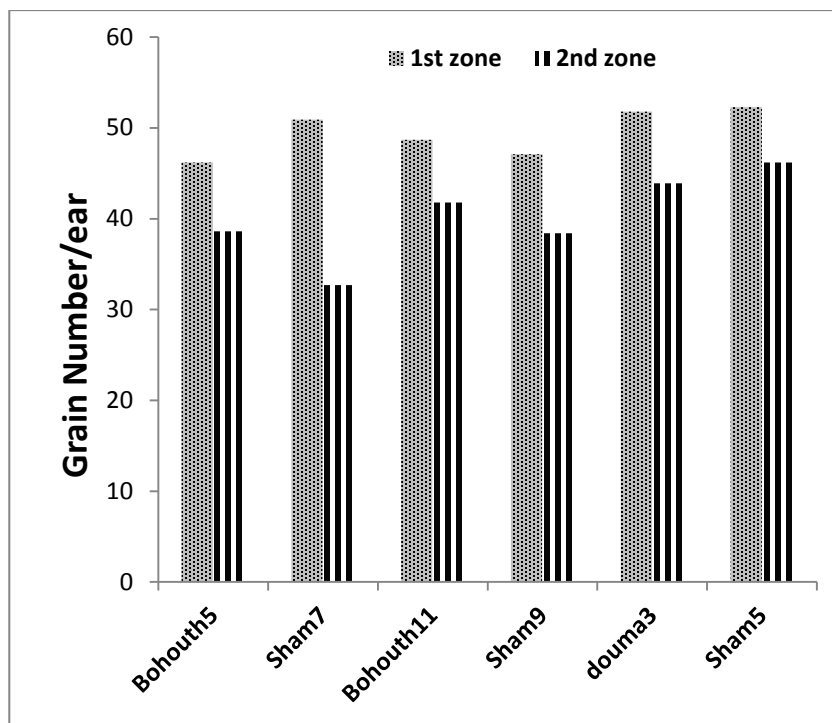


Fig (8). Grain number/ear of tolerant, moderately tolerant and susceptible wheat varieties grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 1.2; Location= 1.7

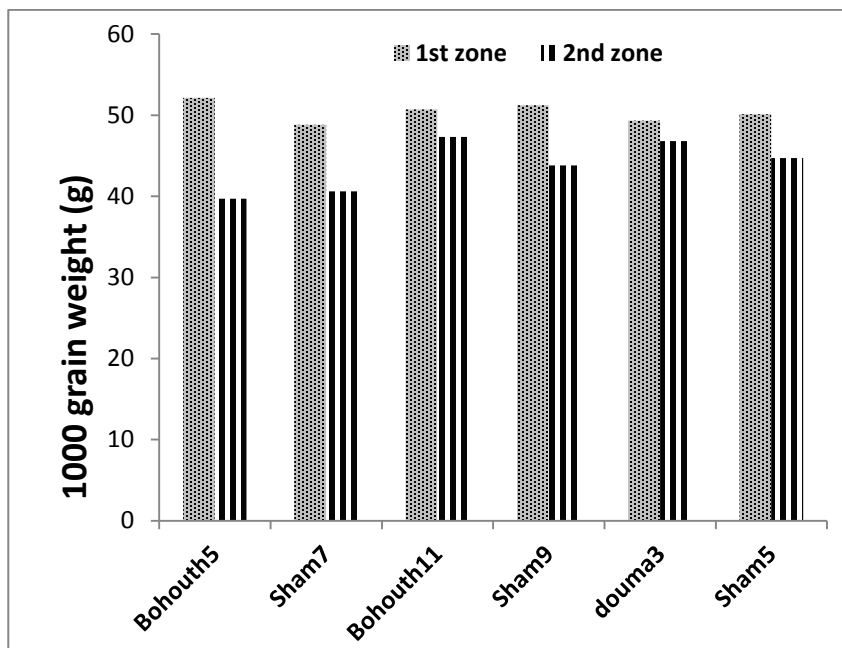


Fig (9). 1000 grain weight (g) of tolerant, moderately tolerant and susceptible wheat varieties grown in the 1st and 2nd settlement zone, LSD values at $P \leq 5\%$: Varieties= 1.1; Location= 0.9

These results are in line with those of Pleijel et al., (2002). Soomro and Oad (2002) also observed significant differences in wheat grain yield of various varieties. These results are in agreement with those of Khan et al., (2005) and Qadir et al., (1999) who observed that 1000-grain weight of wheat was reduced mainly due to increasing water stress. Tompkins et al., (1991) reported the significant

suppressive effect of water stress on number of grains per spike. Khanzada et al., (2001) and Qadir et al., (1999) have earlier reported that water stress throughout vegetative and reproductive development caused a significant reduction in number of grains per spike in wheat

One of the major goals for plant breeders is to develop genotypes with a high yield potential and the ability to maintain yield across environments. This is particularly true in the Mediterranean basin where harsh and fluctuating climatic conditions lead to high Genotype \times Environment (G \times E) interactions. Direct selection for yield in dry environments is inefficient due to large seasonal variation in weather and generally a large genotype \times environment interaction, resulting in low heritability for yield, it would seem that selection for an underlying physiological trait that limits yield could be effective and contribute substantially to yield improvements (Richards et al., 2002). Understanding of physiological mechanisms that enable plants to adapt to water deficit and maintain growth and productivity during stress period could help in screening and selection of tolerant genotypes and using this trait in breeding programs (Zaharieva et al., 2001) and any genetic advance in yield in a dry environment is based on some physiological traits (Richards et al., 2002).

3.6 Correlation Coefficient between Different Physiological Characters and Yield Components

Negative correlation was observed between MSI and plant total biomass at vegetative stage in the 1st zone, while the correlation was positive with grain yield. Also positive correlation between chlorophyll content and grain number/ear and 1000 grain weight. Chlorophyll fluorescence showed positive correlation with total biomass at the same stage. While at anthesis stage MSI showed positive correlation with grain yield, grain number/ear and 1000 grain weight, at the same stage positive correlation between RWC and grain number/ear and 1000 grain weight and positive correlation between chlorophyll content and the grain number/ear and 1000 grain weight also correlation between chlorophyll fluorescence and grain yield was recorded as shown in (table 2a and 2b).

Table (2a, 2b). Correlation coefficient (r) between various physiological traits (membrane stability index, relative water content chlorophyll content, chlorophyll fluorescence) and yield components at vegetative (a) and anthesis stage (b) in the 1st settlement zone.

Vegetative stage				
	MSI	RWC	Chlorophyll content	Fv/Fm
Total Biomass	-0.84**	0.32	-0.19	0.62*
Grain Yield	0.98**	-0.21	0.1	-0.49*
Tiller Number	0.14	0.32	0.24	-0.18
Grain number/ear	0.21	-0.12	0.79**	-0.41*
1000 grain weight	0.03	0.17	0.73**	0.57*

(2a)

Anthesis stage				
	MSI	RWC	Chlorophyll content	Fv/Fm
Total Biomass	-0.62*	0.18	-0.23	-0.28
Grain Yield	0.86**	0.24	0.45*	0.67*
Tiller Number	-0.05	0	0.47*	-0.1
Grain number/ear	0.6*	0.72**	0.86**	0.56*
1000 grain weight	0.6*	0.85**	0.89**	0.34

(2b)

* Significant at 5%: 4-6; ** Significant at 1%: 7-9

In the 2nd zone strong negative correlation between chlorophyll content and tiller number at vegetative stage and positive correlation between MSI and total biomass, grain yield and 1000 grain weight at anthesis stage, at the same stage positive correlation was recorded between RWC and tiller number and grain number/ear and positive correlation was observed between chlorophyll fluorescence and grain yield as observed in (table 3a and 3b).

Table (3a, 3b). Correlation coefficient (r) between various physiological traits (membrane stability index, relative water content chlorophyll content, chlorophyll fluorescence) and yield components at vegetative (a) and anthesis stage (b) in the 2nd settlement zone.

vegetative stage				
	MSI	RWC	Chlorophyll content	Fv/Fm
Total Biomass	-0.19	-0.33	0.29	-0.31
Grain Yield	-0.13	0.24	0.31	0.32
Tiller Number	0.47*	0.42*	-0.94**	0.53*
Grain number/ear	0.12	-0.04	-0.2	-0.42*
1000 grain weight	0	-0.17	-0.21	0.09

(3a)

Anthesis stage				
	MSI	RWC	Chlorophyll content	Fv/Fm
Total Biomass	0.61*	0.02	0.22	0.24
Grain Yield	0.76**	0.32	0.38	0.71**
Tiller Number	0.18	0.89**	0.41*	-0.09
Grain number/ear	0.48*	0.68*	0.12	0.09
1000 grain weight	0.57*	0.57*	0.22	-0.06

(3b)

* Significant at 5%: 4-6; ** Significant at 1%: 7-9

4. Conclusion

The conclusions are that all of these traits have directly or indirectly transfer their effects to yield over long time scales and can be shown to have these effects through influencing photosynthetic rate, protecting the cell from damage that may occurs due to water scarcity. Photosynthesis is sensitive to heat and drought stresses and it is often the first process that is affected by stress. Various traits are linked strongly to photosynthesis like chlorophyll content and components, chlorophyll fluorescence, relative leaf water content and some leaf pigments.

Growth and photosynthesis are two of the most important processes abolished, partially or completely, by water stress, and both of them are major cause of decreased crop yield. The best option for crop production, yield improvement, and yield stability under soil moisture deficient conditions is to develop drought tolerant crop varieties. Looking overall results, it is clear that these parameters could explain some of the mechanisms which indicate tolerance to drought; however, their relevance in describing the varieties variability is significant.

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