Pak. J. Bot., 50(4): 1281-1289, 2018.

PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES IN SOME ALMOND (*PRUNUS AMYGDALUS* BATSCH.) GENOTYPES (GRAFTED ON/GN15) SUBMITTED TO DROUGHT STRESS

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Abstract

The concept of plants reactions to drought conditions is important for improving water-use efficiency (WUE). In this research several physiological traits including: relative water content (RWC), leaf water potential (Ψ_w), photosynthesis rate (P_N), stomatal conductance (g_s), leaf temperature (ΔT), electrolyte leakage (E_L) of five almond genotypes grafted on/ GN15 rootstock, which exposed to drought stress were studied. Drought tolerance according to some parameters was specified in different genotypes. In all genotypes, as the level of drought severity increased, RWC (up to 32%), Ψ_w (up to -3.38Mpa), photosynthesis rate (up to 70%) and leaf stomatal conductance (up to 75%) significantly decreased; whereas, electrolyte leakage (up to 53%), and leaf temperature increased. Water deficit significantly elevated WUE more than 7 times in the drought-resistance genotypes. The differences in ΔT in the early morning and midday significantly decreased in drought-tolerant genotypes. Significant ($p \geq 0.01$) correlation between ΔT, P_N and g_s were found. It can be concluded that ΔT might be utilized as an easy evaluation in order to estimate drought stress in almond genotypes and controlling drought stress in the irrigation programs of almond trees. In other words, in comparison, "Ferragness" cultivar, "Sahand" and H genotypes on GN15 rootstock could act more efficiently than other genotypes, especially during severe drought stress conditions. This is related to decreases in stomatal conductance and more ability to maintain RWC.

Key words: Almond rootstocks, Drought tolerance, Photosynthesis, Stomatal conductance, Water potential.

Introduction

Almond (*Prunus amygdalus* Batsch.) one of the most valuable nuts, grown under the Mediterranean conditions, is very adjusted to a different amount of soil water content (Alarcon *et al*., 2002; De Herralde *et al*., 2003; Isaakidis *et al*., 2004). It was reported that almond was native to the Iranian plateau and export of the products was important (Rouhi *et al*., 2007). Iran is in the main source of almonds genotypes which are rich in native varieties as very late flowering and tolerant trees to dry conditions. Iran's arid and semi-arid areas have an average rainfall of about 141 mm yr^{-1} (Kafi *et al*., 2000). On one hand, almond yield may be reduced at these conditions, because almond trees are developed in lands with 600 mm yr^{-1} rainfall (Romero *et al*., 2004). On the other hand, under controlled irrigation management and use of suitable cultivars, or rootstocks (drought tolerant), the satisfactory yield can be achieved (Rouhi *et al*., 2007). It is reported that almonds yield may reduce from 42 to 55% during dehydrated soil situations (Gomes-Laranjo *et al*., 2006). Various almond cultivars and genotypes were exhibited multiple reactions under water deficit situations (Matos *et al*., 1998; De Herralde *et al*., 2003; Rouhi *et al*., 2007; Yadollahi *et al*., 2011). Physiological plant responses depend on the plant species, the nature and duration of the drought stress (Ruiz-Sanchez *et al*., 1993; Jabeen *et al*., 2008), the compatibility to a specific amount of water content and the conformity to water deficit (Alscher & Cuming, 1990). Understanding of drought endurance tools creates it easier to plant utilizing lack watering approaches invented to keep water while lessening the adverse influences on the yield or plant recovery (Domingo *et al*., 1996). The decline in RWC of leaves primarily causes stomatal closing, a decrease in the amount of CO_2 to the mesophyll cells and, subsequently, a decrease in the level of leaf photosynthesis (Lu & Zhang, 1998). It has been mentioned that growth and yield during drought stress in almonds may be related to decreasing in photosynthesis (Romero *et al*., 2004). Reduction in stomatal conductance, netphotosynthesis and evapotranspiration (E) in the almond trees during water deficit status has been revealed in many reports (De Heralde *et al*., 2003; Romero *et al*., 2003; Isaakidis *et al*., 2004; Rouhi *et al*., 2007). Genotypic variation acted as a principal part of the abovementioned declines with respect to photosynthesis in almonds during drought stress. Canopy leaf temperature, leaf water potential, growth, plant height and Trunk cross sectional area as a sign of drought stress are important (Karimi *et al*., 2015; Buraknazmi & Senih, 2010). It is essential to comprehend the physiological reactions of different genotypes to a different range of water deficit to evaluate the onset of stress levels, moreover, to recognize susceptive and more tolerant genotypes for breeding programs in almonds. Hence the objective of this experiment was to identify water relations, photosynthetic parameters and difference in leaf temperature in the morning and noon in three Iranian genotype named "K3-3-1", "H" and "13-40", and the French and Iranian cultivars named "Ferragnès" and "Sahand" and to screen for moderate and severe water stress.

Methods and Materials

Plant material and experimental design: This study was performed at the Research Center of Agriculture and Natural Resources of East Azerbaijan, Sahand Station, Iran, during 2014-2016 growing seasons. The plant materials, applied in our study, involved two almond (*P. amygdalus* Batsch.) cultivars: "Ferragnès" and "Sahand" and three superior genotypes: "K3-3-1", "H" and "13-40" (recently introduced with excellent yield, late bloom properties, and endurance to freeze). Some main traits of selected cultivars and hybrids are given in Table 1.

Initially, all healthy scions were achieved from The Almond Collection Orchard of the Horticultural Research Section, Seed and Plant Improvement Institute (SPII), Karaj, Iran, in 2014. Then they were grafted on the uniform GN15 rootstocks (cross between the Spanish almond "Garfi" [(*Prunus amygdalus* Batsch, syn. *P. dulcis* (Mill.) D.A. Webb] as the female parent and the North American peach 'Nemared' [P. persica (L.) Batsch] as the pollen donor) in summer 2013 (Felipe, 2009). Uniform grafted plants were relocated to pots (volume 20 L and diameter 40 cm) at the end of 2014. Then all experimental plant materials were grown in a greenhouse at the normal daylight conditions. The temperature regulated averagely at 25°C and also relative humidity controlled between 55-65%. Four months later, the plants were exposed to drought stress. The soil was salty loam contained humus, soil and sand (1:1:1, v/v/v). The soil profile is shown in Table 2.

Deficit irrigation treatment was in 3 levels: full irrigation (as control, irrigated up to soil field capacity moisture); 70% (-0.8MPa) and 40% (-1.6MPa) field capacity, which they were applied from15 July to end of August (for 45 days). Volumetric balance method (based on drainage lysimeter) was used to determine water requirement (the following formula):

$$\Delta S = I - O$$

I: Feed water to the pot,
O: Water drained from the bottom of the pot and
ΔS: Compensate for the moisture out of the soil between two watering due to evapotranspiration.

The soil water retention curve of the experimental soil needed to measure the water content of the soil field capacity was measured which presented in Fig. 1 (Jimenez *et al.*, 2013).

Table 1. Some features almond cultivars/genotypes and hybrids used in the study.

Characteristic	Varieties/genotypes				
	"13-40"	"H"	"K-3-3-1"	"Ferragnès"	"Sahand"
Origin (produce)	Selection of Qazvin region	Hybrid (Shokofe × ferragnès)	Op. Tardy Nonpariel	France	Selection from East azerbaijan
Flowering time	Late flowering	Late flowering	Very Late flowering	Late flowering	Late flowering
Fertility	Very fruitful	fruitful	Very fruitful	Very fruitful	fruitful
Fruit bud	Spore	mixed	mixed	Spore	Spore
Fruit size	Relatively large	Medium	Medium	Large	Large
Tree growth habit	Widespread	Vertical half	Vertical half	Vertical	Vertical
Fruit skin type	hardy	Thin-skinned	Thin-skinned	Half stone	hardy
Kernel (%)	30%	50%	55-60%	32%	35%
Twin Kernel	No twin	No twin	No twin	No twin	No twin
Self-incompat.	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible

Table 2. Soil Profile Properties which was used in the study.

Texture	Calcium solution (ppm)	Absorbable K (ppm)	Absorbable P (ppm)	(%O.C)	(N%)	(pH)	Salinity EC (dSm^{-1})	Saturation (S.P%)	Depth (cm)
Salty loam	1030	854	68.9	1.54	0.16	7.6	20.02	29	

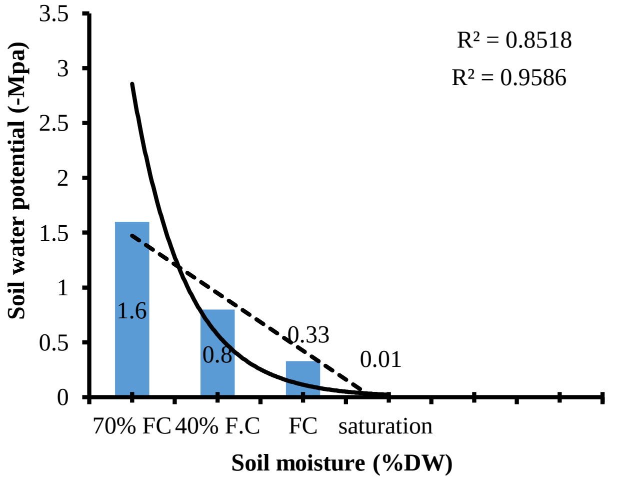

Fig. 1. Soil water retention curve of the experimental soil.

At the beginning of the experiment, plants were irrigated every two days (during 2 weeks) and from the second half of August, and at the end of the experiment watering was done on a daily basis.

Some main physiological attributes such as water relations, Ψ_w, RWC were measured weekly. Furthermore, electrolyte leakage percentage (%EL), morning leaf temperature (T1) and midday leaf temperature (T2), the temperature difference between morning and midday (ΔT), gas exchange properties including P_N, g_s E, and WUE of almond genotypes/cultivars were measured. The leaf RWC (separated from the middle branches) was measured according to the Kirnak *et al.*, (2001) method. The leaf water potential (from a fully developed leaf in the middle branches just before irrigation in the midday) was measured weekly by the pressure chamber (SKPM 1400, Skye Instruments, UK). The leaf temperature (in fully developed leaves of the middle branch) was estimated by using a laser thermometer (LI 6400), in the morning and midday for each plant. In addition, the leaf gas exchange properties including P_N and E, stomatal conductance index using Photosynthesis meter (LI-6400, LICOR, Lincoln, NE, USA) and WUE (using the formula WUE=P_N/E) were measured. Also, the electrolyte leakage percentage (%EL) was evaluated according to the Zhao *et al*., (1992). Data were analysis using statistical software MSTATC and then a comparison of means was done with Duncan test.

Results

The results of this experiment indicated that initially there were not any significant (P= 0.01) differences among Ψ_w of all genotypes and cultivars which were grafted on GN15 rootstock, but from the second week, leaf Ψ_w decreased gradually. Firstly, it was observed in the genotypes of K3-3-1 and 13-40 (in the moderate stress conditions, which was equal to -0.8 Mpa); and from the third week, when there were sever stress conditions (-1.6 Mpa), as a reaction to the decline of soil water amount, the Ψw in all the genotypes was significantly decreased (Fig. 2). Under severe stress condition, "Ferragness", "Sahand" cultivars and "H" genotype actively compensate leaf Ψ_w and water potential was promoted from the fourth week and fixed at the end of the experiment and there was no significant difference together. While "K3-3-1" and "13-40" genotypes showed a significant reduction of Ψ_w (Fig. 2).

Relative water content (RWC) in control plants were almost at the same level. Under moderate stress (Ψ_w = -0.8 Mpa), RWC was decreased in all genotypes/cultivars and a significant reduction (p>0.01) was found with control plants. With rising drought stress (Ψ_w= -1.6 Mpa) there was a continued decline in RWC, So that in the "Sahand" and "Ferragness" cultivars remained constant but the decline continued in "13-40" and "K3-3-1" genotypes and in the fifth week faced. There was a sharp decline in RWC and their leaves were abscised (data not shown) (Fig. 3).

Electrolyte Leakage percentage was lowest in the control plants. Increasing water stress, promoted electrolyte leakage percent. Under moderate stress (Ψ_w= -0.8 Mpa), among the varieties/genotypes, the greatest decrease membrane integrity index was found in "13-40" and "K3-3-1". The maximum electrolyte leakage was observed during severe stress conditions. Increasing severe drought stress promotes the amount of electrolyte leakage from 53% to 58% in "K3-3-1" and "13-40" respectively. Electrolyte leakagein "H" genotype was at a medium level (Fig. 4).

Drought stress reduced P_N in all genotype/cultivars. There was no significant difference among reductions of net photosynthesis rate in all treatments, when genotypes exposed to mild stress (Ψ_w= -0.8 Mpa), except "K-3-3-1" genotype (Table 3). The least P_N was recorded at the end of severe drought stress and the least of net photosynthesis rate related to "K3-3-1" and "13-40" and somewhat "H" genotype and its value was less than 3μmol CO_2 m^{-2} s^{-1} (Fig. 5 and Table 3). Under drought stress, g_s of leaves decreased significantly. No significant differences were obtained between mild and severe drought stress levels, but the greatest amount of g_s were observed in the control plants (well-irrigated plants) and the lowest was observed in the severe stress. In addition, no significant differences between genotypes/cultivars were observed (Table 3).

Water evaporation rate (E) from almond cultivars/ genotypes leaves increased under drought stress. In the measurement of mild drought stress, the intensity of evaporation in "Sahand", "ferragness" and "H" genotype had no significant difference with control treatment but in the other cultivars significantly less than the control plants. The lowest intensity of evaporation was observed from 0.33 to 0.38 mmol H_2O $m^{-2}s^{-1}$ at the end of the period of severe drought.

According to Fig. 6, WUE was significantly increased under drought stress conditions. The WUE of "Ferragnès", "Sahand" and "H" did not significantly affect by moderate drought stress as compared with control plants. But the greatest amount of WUE was found at the end of severe water deficit level (-1.6 Mpa) in leaves of this cultivar /genotypes. Leaves of "13-40" and "K3-3-1" did not make a big difference in WUE during severe drought stress (-1.6 Mpa) (Fig. 6). WUE enhanced significantly in "Ferragnès" (11.47) and "H" (11.12) respectively, when measured at severe drought stress which was higher than other genotypes. WUE in leaves of the "Sahand" increased to 8.84 mmol H_2O $m^{-2}s^{-1}$, which was higher than the other ("13-40" and "K3-3-1") genotypes. Table 3 shows leaf temperature in the morning, midday and the temperature difference between morning and midday in almond cultivar/genotypes. Under drought stress (moderate and severe) leaf temperature in the morning was not significant between genotypes compared to control plants, but the mild and severe drought stress significantly caused the leaves in the midday heat up and significant differences were seen between genotypes. The significant negative relationship was found between temperature difference between morning and midday (ΔT), P_N and g_s (Table 4).

Table 3. Effects of water stress on morning, midday temperature (T1 and T2) and leaf relative temperature (ΔT), net photosynthetic rate (P_N) and stomatal conductance (g_s) in the leaves of almond genotypes.

Main factors	Morning temperature(T1)	Midday temperature (T2)	difference between morning and midday (ΔT)	Stomatal conductance gs [μmol (CO2) m^{-2} s^{-1}]	Net photosynthesis P_N [μmol(CO2) m^{-2} s^{-1}]
Drought stress					
Control	18.93 a	41.73 b	22.8 b	0.118 a	12.30 a
S1	19.50 a	43.77 ab	24.27 a	0.0148 b	10.547 a
S2	19.87 a	44.83 a	24.96 a	0.0032 b	3.387 b
Cultivar					
Sahand	19.05 c	41.08 b	20.78 c	0.0456a	6.456 bc
Ferragness	19.12 c	40.21 bc	20.66 c	0.0502a	7.289 a
13-40	20.5 a	42.50 a	24.79 ab	0.0437a	5.844 d
H	19.25 b	41.30 b	22.32 bc	0.0446a	6.500 b
K3-3-1	20.78 a	43.44 a	25.32 a	0.0433a	5.967 cd

C: control (Ψ_{soil}= -0.33MPa), S: moderate (Ψ_{soil}= -0.8Mpa) and S2: severe stress (Ψ_{soil} =-1.6 MPa) and five almond cultivar/genotypes includes: 'Sahand', 'Ferragnes', '13-40', 'H' and 'K3-3-1' on GN15. Values by the same letter do not differ significantly according to the Duncan's multiple range test (p≤0.05)

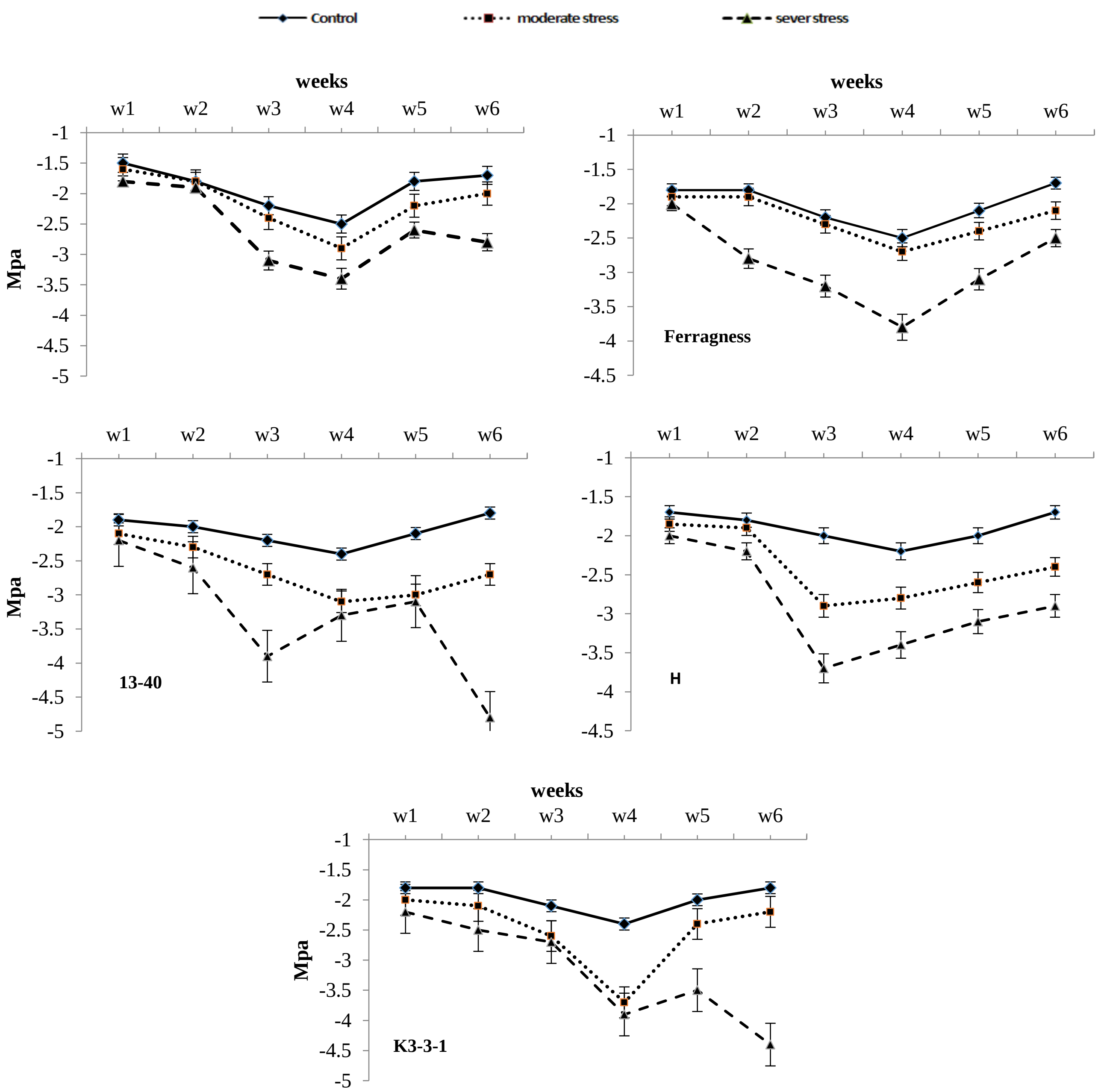

Fig. 2. leaf water potential (Ψ_w) (MP_a) in 5 cultivar and genotype grafted on GN15 during 6 weeks of drought stress. Each point indicates the three replications and vertical markers ± SEM.

Discussion

In the present research under water stress, gradual reduction of Ψ_w and RWC in the leaves of almond genotypes was observed. In a mild stress, RWC of genotypes was not affected much, but Ψ_w significantly reduced in all genotypes. Moreover, it was revealed that osmotic adjustment mechanism of genotype by most almonds to regulate and keep the pressure constant (Turgor) and leaf turgor pressure and photosynthesis maintaining during drought stress applied in the first stages. Campos *et al*., (2005) and the Karimi *et al*., (2013) revealed that the assemblage of proline and soluble carbohydrate in the osmotic adjustment of almonds leaves has been involved. The lowest values of leaf water potential and RWC in the genotypes "K3-3-1" almond "13-40" and partly in "H" genotype at the end of severe drought period that is associated with the wilting, yellowing, necrosis and defoliation leaves was observed.

Ψ_w was different in the control plants of genotypes that it may be caused by the osmolytes in their leaves. The most leaf water potential was obtained in the "Sahand" and "H" genotypes and the lowest in "K3-3-1" genotype. At these conditions, reactive oxygen species (ROS) causes cells dehydration during drought stress that leading to the oxidative destruction of different cell components and photosynthesis organs (Tang *et al.*, 2002, Bian & Jiang, 2009). Ψ_w was different in the control plants of genotypes that it may be caused by the osmolytes in their leaves. The most leaf Ψ_w was observed in "Sahand" cultivar and "H" and lowest it was in "K331" genotype. This due to the production of ROS during drought, they cause the cells to become dehydrated which cause oxidative damage to cell membranes and other parts, organs and photosynthesis organs (Tang *et al.*, 2002; Bian & Jiang, 2009). The decrease of cell membrane stability in almond genotypes parallel to reduce the RWC leaves and dehydrate cells occurs. Electrolytes Leakage in associated with preserving the stability of plant cell components. A significant increase in electrolytes leakage of "K3-3-1" and "13-40" almond genotypes under moderate stress may be associated with higher susceptibility genotypes to water scarcity and the loss of their leaves water. As demonstrated in this study, similar research preserving the integrity of cell membranes in the leaves of plants tolerant to water deficit has been stated (Bukhov *et al.*, 1990; Bajji *et al.*, 2002; Karimi *et al.*, 2015). Sivritepe *et al.*, (2008) and Karimi *et al.*, (2015) reported that membrane stability index decreased by drought stress and differences among different genotypes. In the present research leakage of electrolytes of the control trees of all cultivars and genotypes was too low (the lowest in genotype "H" and highest in "K3-3-1"). Results from Fig. 4 showed the maximum injury in genotype "K3-3-1" and "13-40" happened and these genotypes are very sensitive to severe stress (-1.6 MPa).

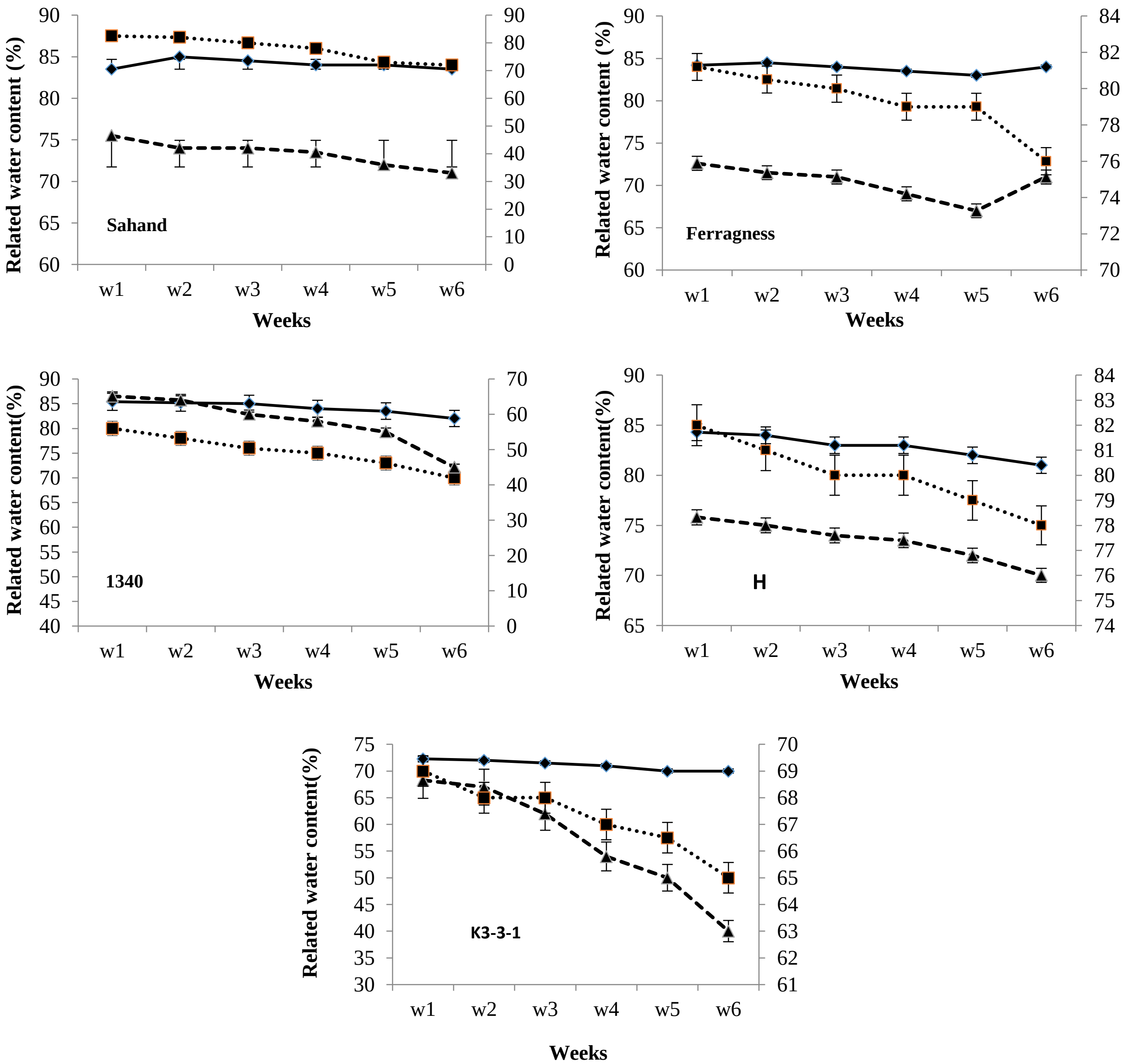

Fig. 3. leaf relative water content (RWC) (%) in five studied genotypes and cultivar on GN15 during 6 weeks of drought stress. Each point is the expression of the 3 repetitions and vertical markers indicate error standard (±SEM .

Stomata conductivity reduction during water stress conditions is an adjustment mechanism in these circumstances that is provided by plants to minimize the loss of water is applied. It was found that even mild stress conditions significantly reduced Stomata conductivity that decreases P_N in some almond genotypes. P_N reduction of "13-40", K3-3-1" and somewhat in the "Ferragness" mild stress is showing the susceptivity of these genotypes to drought. Maintain the amount of leaves P_N in the "Ferragness", "Sahand" cultivars and somewhat "H" in under severe stress conditions can suggest less damage cell walls, extra compatibility with high temperatures and more osmotic adjustment power in the genotypes (Herppich & Peckmann, 1997). Stomatal conductance control and transpiration reduce leaf temperature to avoid overheating. In this research, the temperature difference between leaves in the morning and midday (ΔT) along with increasing drought stress significantly increased. The range of ΔT, between 20.66°C in "Ferragness" cultivar to 25.32 in "K3-3-1" genotype was recorded at the end of severe drought stress. A negative correlation was found between the g_s and ΔT the negative relation between ΔT and g_s suggested that a reduced g_s triggered ΔT elevation.

With the decline of g_s leaf temperature difference increased. In the genotype "K3-3-1" and "13-40" temperature difference between in the morning and midday (ΔT) was much higher than in "Ferragness", "Sahand" and "H" genotype. Despite the non-significant differences in temperature in the morning the temperature in the midday between varieties and genotypes significant differences were revealed in the severe water deficit situation that is probably due to severe dehydration leaves in "k3-3-1" and "13-40" genotypes. Similar results to relate with leaf temperature deference and leaf temperature in research of Karimi *et al*., (2015) was reported. Our results showed that "Ferragness", "Sahand" and somewhat "H" on GN15 rootstock have the ability to maintain photosynthesis under leaf high temperature and g_s reduction that may possibly be linked to their drought endurance activities.

It is reported that photosynthesis is very susceptive to abnormal temperatures (Berry & Björkman, 1980). The adverse relationship between temperature difference between morning and afternoon (ΔT) and P_N indicates that high temperature in the leaves is symmetrical with the highest level of water deficit (Table 5). Schapendonk *et al*., (1989) concluded that the rise of leaf temperature during water deficit situations diminishes the quantum performance. Discord and inequality between photochemical processes of photosystems II and electronic need for photosynthesis caused light reduce during such circumstances (Epron *et al.*, 1992; Karimi *et al.*, 2015). Increase the temperature in the leaves of almond, the increasing net photosynthesis during water deficit status shows that light preventing phenomenon has happened. But since g_s is reduced directly by leaf water stress, separating the unilateral influences of drought stress from influences of high leaf temperature in the reduction of photosynthesis is difficult (Gates, 1968). Obtained results propose that restriction in P_N under the mild water deficit conditions, that initially caused by the closure of the stomata. Furthermore, the exacerbation of the heat and cell damage in reducing the P_N under long-term drought stress involved and engaged. The results also show that the application of temperature difference in the morning and midday (ΔT) as a simple and inexpensive method to assess g_s of almond leaves.

When the temperature difference between midday and morning reaches higher than twice may decrease in the P_N to more than 50% and 80% in the g_s and this can determine the critical point at the time of watering the almond trees will be useful. Maintaining the P_N under reduced g_s and E during drought stress course leading to increasing WUE. Boyer (1982) concluded that the WUE is vital to plant endurance and its normal growth, development and yield. Greater WUE during water shortage status might be an outcome of adjustment of the gas exchanges. The parameter E (evaporation and transpiration) is more affected by drought as compared with the P_N. Tolerant cultivars have high water consumption efficiency during the water shortage status that shows their capacity to retain water and support the physiological processes during drought stress condition (Karimi *et al.*, 2015). The present results are in agreement with findings of Escalona *et al*., (1999) and Bota *et al*., (2001). Furthermore, the pretty great WUE which observed in susceptive cultivars (such as "K3-3-1") to drought stress could be linked with drastic water deficit and also very low E as mentioned by Karimi *et al*., (2015). According to the P_N/E ratio, shows an increase photosynthetic performance in the almond trees during water stress, recommended other physiological reactions associated with WUE in order to investigate for stress tolerance in these varieties.

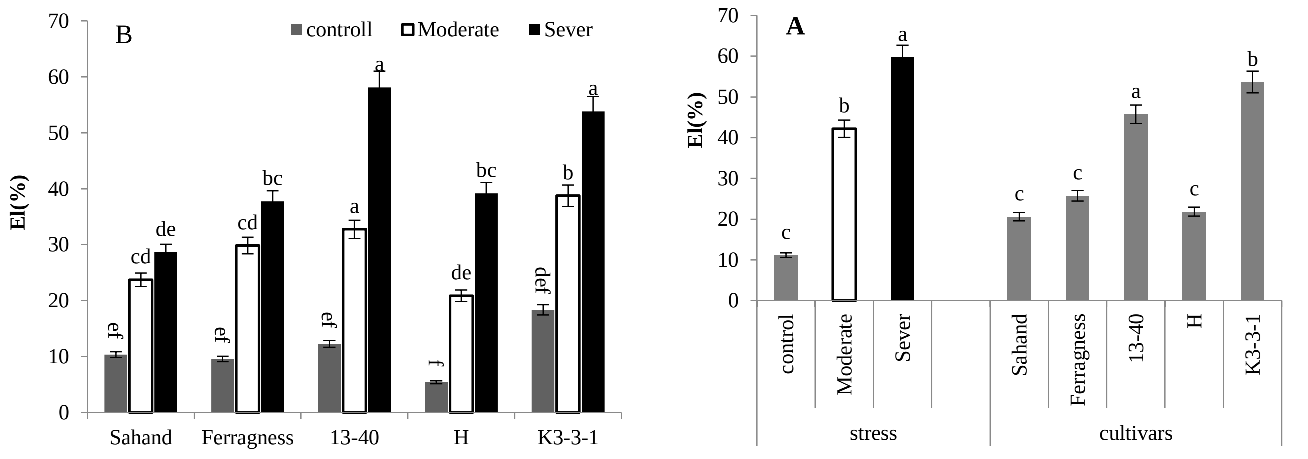

Fig. 4. Comparison of the electrolyte leakage (EL) averages in five studied almond genotypes/ cultivar on GN15. A: In drought stress treatment and cultivars, B: Interactions between cultivars and drought stress. Similar letters in each column of each section represents the lack of significant differences in the level 0.01.

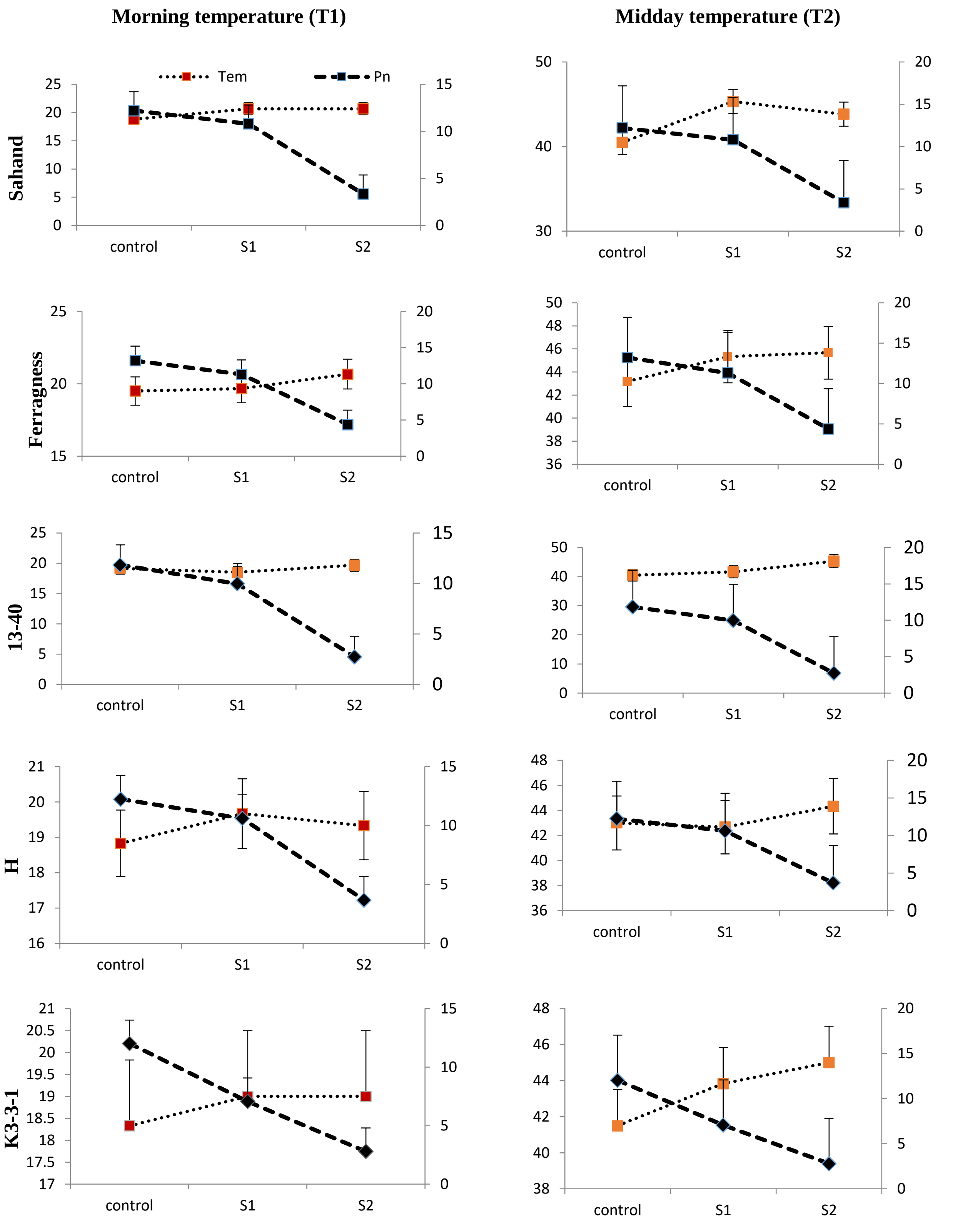

Fig. 5. Relationship between the leaves temperature on the morning (left) and midday (right) with net photosynthesis (Pn) at leaves of 5 genotypes/ cultivars on GN15 under drought stress (S_1: mild stress and S_2: sever stress)

Table 4. Interaction effects of water stress and cultivars on morning, midday temperature (T1 and T2) and leaf relative temperature (ΔT), net photosynthetic rate (P_N) and stomatal conductance (g_s).

Cultivars	Morning temperature (T1)	Midday temperature (T2)	difference between morning and midday (ΔT)	Stomatal conductance gs [μmol (CO2) m^{-2} s^{-1}]	Net photosynthesis P_N [μmol (CO2) m^{-2} s^{-1}]	Drought stress
Sahand	18.83 b	40.50 d	21.57 de	0.1150 a	12.20 b	Control (C)
Ferragness	19.50 ab	41.17 cd	20.57 de	0.1273 a	13.20 a	
13-40	19.17 b	42.50 bcd	23.47 bcd	0.1173 a	11.83 b	
H	18.83 b	41.00 bcd	21.93 cde	0.1170 a	12.23 b	
K3-3-1	18.33 b	43.50 abcd	24.90 b	0.1160 a	12.03 b	
Sahand	20.67 a	41.33 cd	20.87 de	0.0180 b	3.800 d	M. Stress (S1)
Ferragness	19.67 ab	40.33 d	21.53 de	0.0193 b	4.300 c	
13-40	18.50 b	42.67 bcd	25.13 ab	0.0120 b	2.967 ef	
H	19.67 ab	41.67 bcd	22.0 cde	0.013 b	3.600 d	
K3-3-1	19.00 b	43.83 abcd	24.67 abc	0.012 b	3.067 ef	
Sahand	20.67 a	40.83 d	19.90 e	0.0040 b	3.367 de	S. Stress (S2)
Ferragness	20.67 a	41.67 cd	19.87 e	0.0040 b	4.367 c	
13-40	19.67 ab	45.33 a	25.77 ab	0.0020 b	2.733 f	
H	19.33 ab	41.33 bc	23.03 bcd	0.0040 b	3.667 d	
K3-3-1	19.00 b	45.00 a	26.40 a	0.0020 b	2.800 f	
Significant						
Treatment	ns	*	**	**	**	
Cultivar	ns	*	**	ns	**	
Cultivar× Drought stress	**	**	**	**	**	

Similar letters in each column of each section represents the lack of significant differences in the level 0.01. Water stress: Control (Ψ_{soil}= -0.33MPa), S1: Moderate (Ψ_{soil}= -0.8Mpa) and S2: Severe stress (Ψ_{soil} =-1.6 MPa)

Table 5. Linear correlation (r) between some studied characters.

	Photosynthesis rate	Evaporation rate	Stomatal conductance	Leaf temperature	R.W.C	E.L	L.W.P
Photosynthesis rate	1						
Evaporation rate	0.77**	1					
Stomatal conductance	0.71**	0.80**	1				
Leaf temperature	-0.70**	0.63**	0.57**	1			
R.W.C	0.76**	0.71**	0.73**	0.66**	1		
E.L	-0.48**	-0.40**	-0.40**	-0.14^{ns}	0.63**	1	
L.W.P	0.79**	0.75**	0.76**	0.71**	0.88**	-0.64**	1

****** and ns: Significant at 0.01 level and no significant respectively, L.W.P: Leaf water potential, E.L: Leaf ion leakage, R.W.C: Relative Water Content

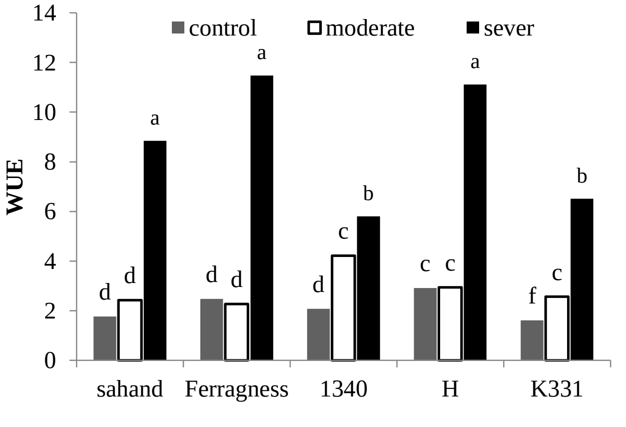

Fig. 6. Relative water efficiency (WUE) in five studied almond genotypes/ cultivars on GN15 rootstock. Similar letters in each column of each section represents the lack of significant differences in the level 0.01.

Conclusion

The present study demonstrates that tolerant almond genotypes ability to maintain its relative water content through osmotic adjustment, retaining wall and less injury to cell components (%EL), high capacity of P_N and high WUE, low g_s and the leaves have relatively low temperatures. "Sahand", "Feragness" and "H" genotype as tolerant cultivars/ genotype and "K3-3-1" and "13-40" as the sensitive genotypes to water shortage according to the studied parameters were divided. Reasonable correlation between ΔT, g_s and P_N in different amount of available water for the almond genotype suggesting that the reasonable relationship between temperature difference on in the morning and in the midday (ΔT), guiding the stomata (g_s) and photosynthesis (P_N) in different amount of available water for the almond genotype suggesting that ΔT is a measurable parameter of quick and simple to show photosynthesis and almond orchards irrigation management can be applied. But the measurement of ΔT requests to be more accurate tools and researchers to make this application.

Acknowledgements

This research project has been supported by the University of Zanjan. Provision of plant material by the Seed and Plant Improvement Institute (SPII), Karaj, Iran is greatly appreciated. Especial thanks the Institute of Water and Soil Research and East Azerbaijan Agricultural and Natural Resources Research and Education Center are also due for their help.

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(Received for publication 1 July 2017)