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Effect of Water Deficit on Biochemical and Growth of Sesame in the Middle East Euphrates Valley

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ABSTRACT
Among the abiotic stresses, water stress is considered to be one of the major limitations on plant growth, yield, quality and nutritional status for sustainable agriculture worldwide. Water is an indispensable planetary natural resource essential to all life and central to bio economy, agriculture and food security. Yet 80% of the global society is exposed to water insecurity. Addressing water deficit and associated risks are prominent in the post-2015 proposed Sustainable Development Goals (SDGs) by United Nations. We report the impacts of water deficit on sesame growth, oil yield, fatty acid composition and mineral content of *Sesamum indicum* L. (Osmanlı cv. versus Muganlı-57 cv.) aerial/edible parts in Euphrates valley of the Middle-East. Sesame is a major foodstuff particularly in developing countries. This is of the studies on response of sesame to water deficit in two different cultivars of sesame in Euphrates Valley where water-based conflicts and disasters are historically common. According to the study results, strategic outlook on food security, disasters and sustainability were given.

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Orta Doğu Fırat Havzası'nda Su Eksikliğinin Susamın Biyokimyasal ve Büyümesine Olan Etkisi

ÖZET
Su eksikliği, tarımsal üretim alanlarında, toprağın verimliliğini olumsuz etkileyerek bitkinin büyümesi, verimi, kalitesi ve temel besin elementlerinin alımını sınırlandıran en önemli sorunların başında gelmektedir. Su, biyo-ekonomi, tarım ve gıda güvenliği için tüm yaşam ve merkezin vazgeçilmez doğal kaynağıdır. Ancak küresel toplumların % 80'i su güvensizliği ile karşı karşıyadır. Birleşmiş Milletler tarafından 2015 sonrası önerilen sürdürülebilir Kalkınma Hedefleri (SDG) 'de su kıtlığı ve bunlarla ilgili risklerin ele alınması ön plana çıkmaktadır. Bu çalışmada, su eksikliğinin, gelişmekte olan ülkeler için temel besin kaynaklarından olan susam bitkisinin (*Sesamum indicum* L. Osmanlı cv. ve Muganlı-57 cv.) büyüme, yağ verimi, yağ asidi ve mineral içeriğine etkisi araştırılmıştır. Su kaynaklı çatışma ve felaketlerin tarih boyunca alışılagelmiş olduğu yer olan Fırat Havzası'nda yetiştirilen susam bitkisinin su stresi altında vermiş olduğu tepkiler incelenmiştir. Çalışma sonuçlarına, sürdürülebilirlik, felaket ve gıda güveliğine ilişkin stratejik görüşler verilmiştir.

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INTRODUCTION

Water is one of the greatest planetary natural resources: it is essential to sustain all life and central to bioeconomy, agriculture and food security. Yet 80% of the world's population is exposed to water insecurity and that 65% of freshwater resources are under threat of declining biodiversity (Vörösmarty et al. 2010). As we are fast approaching to sign the United Nations Sustainable Development Goals (SDGs) in New York City in September 2015 by the world's nearly 200 governments, there is a need to examine the broader impacts of water deficit (Birko et al. 2015) particularly on food insecurity by virtue of changes in nutritional composition and value of foodstuff. Indeed, addressing water deficit and associated risks such as food insecurity are prominent in the post-2015 SDGs proposed by the Open Working Group (United Nations, 2015).

Among the abiotic stresses, water shortage is considered to be one of the major limitations for sustainable agriculture worldwide (Lefèvre et al. 2012), a key priority concern of relevance for "creation of inclusive and peaceful societies", one of the proposed SDGs (United Nations, 2015). Drought is one of the most damaging abiotic stresses affecting modern day agriculture. Plants are more susceptible to drought during the reproductive stages, as plant's resources are dedicated to support root growth (Oliveira et al. 2013). In our previous study conducted on two different cultivars (Cumhuriyet and Özberk) of sesame, plant growth and related developmental parameters were diminished with the reduction in water supply but no significant changes were determined with respect to the oil yield (Ozkan and Kulak, 2013). Growth and production of sesame are also significantly influenced along with the water stress applied during different growth stages; vegetative, flowering and maturity stage. Herewith, water stress at flowering stage should be avoided to increase seed yield (Nilanthi et al., 2015). Furthermore, the number of irrigation has been associated with the yield of sesame which was decreased with the reduction of the irrigation numbers (Tantawy et al., 2007). Hereby, the quantity, number and stage of stress is a great concern but it must be optimized for each plant species or even cultivars or genotypes.

Effective water management in a context of food security and sustainable development demands knowledge of the impacts of water deficit and drought on foodstuff and food biology and biochemical correlates. In this connection, sesame (*Sesamum indicum* L) is noteworthy because it represents a major source of food consumption, particularly in developing countries (Aubee and Hussein 2002). Sesame is a vegetable oil crop and the demand for vegetable oil worldwide is high as well. Sesame belongs to the division Spermatophyte and family Pedaliacea, thought to have originated from tropical Africa. It is probably the most ancient oilseed crop known and used by man. Sesame is now cultivated in almost all tropical and sub-tropical Asian and African countries, southern European countries, Russia, South and Central America, and on a very small scale in the United States of America.

Surprisingly, despite the synergistic importance of water and sesame supplies for global food and societal security, sesame responses to abiotic stress such as water deficit and its biochemical and growth-related correlates have not been studied hitherto. Moreover, little is known on regional variations on the ways in which water deficit impacts sesame in different world regions. Middle-East is particularly understudied in this very context of water and sesame growth interaction. To the best of our knowledge, we report here the first study on drought response of sesame in two different cultivars of sesame seeds in Middle-East Euphrates Valley where water-based conflicts and disasters are historically common.

MATERIALS and METHODS

Plant material and water deficit treatment

Field experiments were conducted at the Agricultural Practices and Research Center of Kilis 7 Aralık University, Kilis (36.71N, 37.11E), Turkey. The effects of water deficit on sesame varieties (Osmanlı and Muganlı-57 cv.) based on the method by Bettaieb et al. (2009) were determined. In brief, during the first 35 days of the study, plants were irrigated with tap water, and subsequently exposed to different water regimes: 100% (control group: C) or 50% (moderate water deficit group: MWD) or 25% (severe water deficit group: SWD) of field capacity (FC). Experimental soil used was a sandy-clay-loam texture comprised of potassium (313.75 ppm), organic matter (1.53%), salt (0.059) at a set pH (8.1). Experiments were conducted in a greenhouse with a 14 hour photoperiod and lasted 4 months. Mean temperature was kept at 28±2 ºC during daytime and 18±2 ºC at nighttime, respectively, with a relative humidity of 70%. After harvest, seeds were air-dried and stored at 4 ºC until use for further analysis.

Growth and yield parameter measurements

For each treatment, measurement of plant height, seed number per capsule, capsule number, 1000-seed weight, total weight per pod, and single plant yield were evaluated by harvest of four randomly selected plants from each pot.

Oil extraction and fatty acid composition analysis

Oils were extracted from sesame seeds (each 2 g sample) with n-hexane for four hours using a Soxhalet extraction apparatus. Subsequently, the solvent was evaporated under reduced pressure and temperature using a Rotary evaporator (Heidolph). We added 0.1 g of sesame oil to 2 ml n-heptanes into a screw-capped tube for esterification. The fatty acid analyses were conducted according to the official method COI/T.20/Doc.no.24 2001. 0.1 g of sesame oil was taken into screw-capped tube. 2 ml n-heptanes added and shaken. After 0.2 ml methanolic potassium hydroxide was added for esterification, tubes were vigorously shaken for 30 sec after the vials were closed. The supernatant of the solution was taken followed after one hour of incubation at room temperature. Then, the supernatant was put in 2 ml vials for injection.

Fatty acid composition profile determination

GC-FID analyses of fatty acids methyl esters was carried out on a Shimadzu gas chromatography (GC-2010 series) equipped with an Supelco SP 2380 fused silica capillary column (100 m, 0,25 mm i.d., 0,2 µm film thickness). Helium was used as carrier gas, at a flow rate of 3 mL/min. The injection and detector temperature were 140 °C and 240 °C, respectively. The oven temperature was held isothermal at 140 °C for 5 min, then raised to 240 °C at 4 °C /min and held isothermal at 240 °C for 15 min. Injection volume of Diluted samples [1/100 (v/v) in n-heptanes] of 1.0 µL were injected automatically in the split mode (1/100).

The identification of the constituents was based on comparison of the GC-retention times with those of available analytical standards (Larodan Fine chemicals, mixture of 37 components of fatty acids methyl esters). Peak area was used to obtain the percentage of individual fatty acid.

Sample preparation and measurement for mineral content

All plant samples were cleaned, washed by de-ionized water, and dried. Pre-dried samples were de-moisturized at 70 °C for 48 hours in an oven and ground for chemical analysis. 0.2 g of ground samples were immediately placed into burning cup with 5 ml HNO_3 65 % and 2 ml H_2O_2 30%. After the incineration process, the solution was cooled at room temperature for 45 minutes. The extracts were passed through a Whatman 42 filter paper. These filtrates were collected by de-ionized water in a 20 ml- polyethylene bottles and kept at 4 °C in laboratory for ICP-OES analysis. Each sample was analyzed in triplicate.

Statistical Analysis

All experiments were carried out in triplicate and the significance of differences among means were determined at $p < 0.05$ using one way ANOVA followed by Duncan's multiple range test. The results were expressed as mean ± standard error (SE). The type of relationship between variables was determined by Pearson correlation coefficients and multiple linear regression analysis. SPSS 16.0 was used for all statistical analysis.

RESULTS AND DISCUSSION

Effect of water deficit on plant growth, seed yield, and other components

The deleterious effects of water shortage on plant morphology were observed after the second week of treatments and were more pronounced with the severity of drought. Plants of control (C) and moderate water deficit (MWD) irrigations showed better agronomic performances for both cultivars with respect to the plant height; those exposed to severe water deficit levels (SWD) presented thinner stems with fewer, dry, and smaller leaves as reported by previous studies. Thus, under SWD and MWD, the aerial part height was reduced, respectively by 34.4% and 6.02% compared to the control group for Osmanlı cv.; by 31.59% and 3.79% for Muganlı-57 cv. This decrease in stem growth and plant height is likely attributable to shrinkage in response to changes in internal water status or a reduction in chlorophyll content and consequently photosynthesis efficiency (Prasad and Bisht 2011).

We observed that water limitation led to substantial decrease in seed number under MWD and SWD treatment regimens in comparison with control for the Muganlı-57 cv. but plants of MWD level favored better than the control ones for Osmanlı cv. Effect of water deficit to plant seed yield was seen also on regression results (see Tables 1 and 2). Categories of water deficit levels included regression model as dummy variable (reference: C). Multiple linear regression result showed that plant seed yield was significantly predicted by plant height (β = –.003; p<.06), seed number (β = –.003; p<.05), 1000-seed weight, (β = .067; p<.05) seed yield per pot (β = –.151; p<.01) and severe water deficit (Reference: Control) (β = –.243; p<.01). These independent variables explained approximately 78% of plant seed yield.

Table 1. Pearson correlations between plant yield parameters (N=72)

N=72	seed yield/ plant	Plant height	seed number	Capsule number	1000-seed weight	seed yield/ pot
Seed yield/ plant	1					
Plant height	,271*	1				
Seed number	,103	,209	1			
Capsule number	,157	,654**	,202	1		
1000-seed weight	,453**	,363**	,198	,263*	1	
Seed yield/ pot	,718**	,036	,205	,195	,259*	1

**: p<0.01 *: p<0.05

All growth and developmental parameters examined in the current study were positively correlated. Seed yield per plant was positively associated with plant height (r=0,271; p<0.05) and 1000-seed weight (r=0,453; p<0.01). Also, plant height was correlated with capsule number (r=0,654; p<0.01) and 1000-seed weight (r=0,363; p<0.01). The higher plant height favors capsule number and 1000-seed weight according to the present results. In the study on *Nigella sativa* by Fufa (2103), plant height was also positively correlated with capsule number per plant but not statistically significant. Plant height was strongly correlated with capsule number but not significantly correlated with 1000-seed weight in flax varieties (Copur et al., 2006).

Table 2. Multiple regression statistics (Dependent Variable: seed yield per plant)

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	*p*-value	Tolerance	VIF
(Constant)	,245	,106		2,321	,023		
swd_1 (Ref: C)	-,243	,039	-,578	-6,234	,000	,402	2,490
Mwd_1 (Ref: C)	-,033	,032	-,079	-1,025	,309	,586	1,706
Plant Height	-,003	,001	-,164	-1,959	,054	,492	2,034
Seed number	-,003	,001	-,180	-2,848	,006	,863	1,159
1000-seed weight	,067	,023	,189	2,863	,006	,790	1,266
Seed yield/ pot	,151	,015	,708	10,094	,000	,704	1,421

Dependent Variable: **seed yield/ plant**
R^2=.775 adj-R^2=.755 SEE=.09902175 D-W=1.269 F (6; 65) =37.380 (p<.000)

Water deficit effects on growth and yield parameter of sesame cultivars are shown in Table 3. Interestingly, the seed yield was not affected by water deficit for both cultivars. Our results are in contrast with those of Laribi et al. (2009) conducted on *Carum carvi* L. Inadequate photosynthesis due to stomata closure and consequently limited carbon dioxide uptake is one of the major reasons for seed yield reduction under deficit irrigations (Zhu 2001). However, the application of drought at early seed formation to maturity was reported to induce a slight increase in seed yield of sunflower (Karam et al. 2007). 1000-seed weight was not influenced by deficit treatments for both cultivars. This result was in agreement with those of Kim et al. (2007) who reported that deficit irrigations did not influence seed weight of sesame, demonstrating that last responds to post-flowering drought by reducing seed numbers (Laribi et al. 2009).

We would like emphasize that transport to the seed has not been prevented even though there was a decrease in growth during the phase of seed filling and consequently, 1000-seed weight was not substantially influenced by drought for both cultivars, consistent with the literature (Bybordi 2010). To respond the changing environmental and growing conditions, plant behavior can change regarding the biosynthesis of bioactive compounds when subjected to abiotic constraints (Hamrouni et al. 2001; Laribi et al. 2009), instead of yield parameters. The effects of drought on whole-plant processes are variable and can influence seed growth, seed yield, and seed quality but occasionally the adverse effects during one phase or trait can be compensated by recovery and excess growth of other organ or trait. Hence, decline in grain yield can be compensated by increased grain quality and it should be understood that post-harvest quality is much more important than total yield (Prasad and Staggenborg 2008).

Table 3. Water deficit effects on growth and yield parameter of sesame cultivars

	Osmanlı cv.			Muganlı 57 cv.		
	C	MWD	SWD	C	MWD	SWD
Plant height	54.02±2.40^a	50.77 ±0.82^a	35.42±1.45^b	54.93±0,99^a	52.85±1.08^a	37.58±0.87^b
Seed number	41.75±4.94^a	45.83±7.17^a	35.00±6.00^a	33.58±6.53^a	31.75±5.59^a	27.92±3.11^a
Capsule number	9.17±0.17^a	6.75±0.29^b	5.08±0.36^b	6.83±0.79^b	6.50±1.52^b	6.50±0.38^b
1000-seed weight	3.63±0.26^a	3.24±0.11^a	3.12±0.12^a	3.32±0.11^a	3.48±0.58^a	2.95±0.39^a
Seed yield/	0.645±0.059^a	0.473±0.116^a	0.337±0.122^a	0.652±0.13^a	0.448±0.08^a	0.436±0.13^a
Seed yield/ pot	2.983±0.216^a	2.128±0.701^a	2.629±0.186^a	2.762±0.90^a	1.639±0.32^a	2.304±0.61^a

When the ***superscript*** letters are different (e.g., a or b), a statistical difference was observed. Means ± SE in the same row with the same ***superscript*** letter are not significantly different from each other according to Duncan's multiple range test (α=0.05)

Effects of water deficit on oil yield

Based on our experimental results, it was shown that oil yield of Osmanlı cv. was positively affected with the water deficit treatments. Oil yield increased significantly about by 45.88% and 66.66% under MWD and SWD, respectively, in comparison with control (Table 4). However; oil yield of Muganlı-57 cv. was not significantly influenced with drought. These results were in good agreement with the studies reports by Al-Barrak (2006) and Zarei et al. (2010). Even though it was noted that the irrigation intervals and cultivars were not significant on seed oil content (see Zarei et al. 2010) there was statistically difference between sesame cultivars tested herein.

Effects of water deficit on fatty acid composition

To the best of our knowledge, no previous studies were reported in the literature about the effects of drought on sesame seed fatty acid proportions. As it can be seen in Table 4 and Figure 1, lipids extracted from sesame seeds are majorly dominated by palmitic, stearic, oleic and linoleic acid for both cultivars. This fatty acid composition was affected by drought. There was an increase in the proportion of palmitoleic, linoleic, linolenic, oleic, cis-11-eicosenoic, and behenic acid with severity of drought for Osmanlı cv. while the decrease in myristic acid, palmitic acid. Consequently, the large proportions of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) were increased with deficit irrigations. Water deficit decreased significantly the proportion of the major saturated fatty acid (SFA), palmitic acid, in comparison with control. However, drought did not elicit significant changes on the proportions of major SFA, stearic acid of sesame seeds of Osmanlı cv. The major variation of sesame seed lipids subjected to drought consisted an increase of MUFA and PUFAs in favor of the saturated ones (SFA). Severity of water deficit treatments lead to considerably changes in fatty acid compositions of Muganlı-57 cv. The proportions of heptadecanoic, cis-10 heptadecanoic, oleic, cis-11-eicosenoic acid, behenic acid increased with drought in comparison with control while the decrease in myristic, palmitic, stearic, and linoleic acid. In addition, palmitoleic, arachidic, linolenic, and lignoceric acid remained unchanged under drought conditions. Accordingly, the proportion of MUFAs was increased with deficit irrigations. PUFAs were not significantly influenced while SFAs reduced under drought for Muganlı-57 cv. Overall, these results revealed that deficit irrigations tend to increase the degree of unsaturation of sesame seeds. The degree of unsaturation is reported to be the more important factor modulating the membrane fluidity maintenance and plant adaptation processes and mechanisms when the plants are submitted to constraint conditions (Xu and Beardall 1997; Bettaieb et al. 2009). Reduction in cellular water media can elicit modifications concerned with membrane permeability and fluidity owing to fatty acid destruction in the membranes and consequently, leading to the cellular membrane rigidity (Marrink et al. 1996).

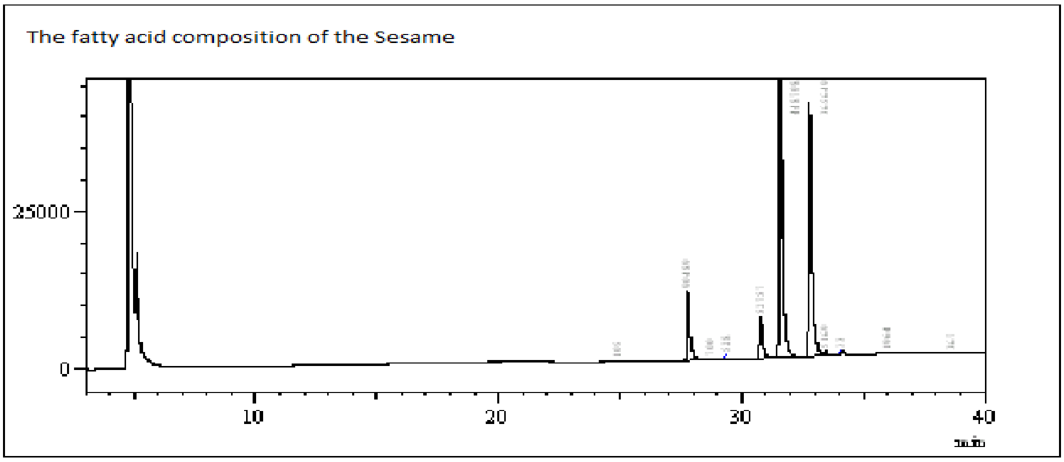

Figure 1. The GC shows the composition of fatty acids at Sesame investigated in this work

Table 4. Effects of water-deficit on total fatty acid composition from sesame seeds of two cultivars

	cv Osmanlı			cv Muganlı 57		
	C	MWD	SWD	C	MWD	SWD
Myristic acid	0.02 ± .00^{a}	0.01 ± .00^{c}	0.02 ± .00^{ab}	0.01 ± .00^{bc}	0.01 ± .00^{bc}	0.01 ± .00^{c}
Palmitic acid	9.51 ± .11^{a}	9.13 ± .08^{ab}	9.14 ± .06^{ab}	9.18 ± .06^{ab}	8.99 ± .24^{b}	8.79 ± .05^{b}
Palmitoleic a.	0.12 ± .00^{a}	0.11 ± .00^{a}	0.12 ± .01^{a}	0.11 ± .,00^{a}	0.13 ± .02^{a}	0.11 ± .00^{a}
Heptadecanoic	0.70 ± .01^{b}	0.07 ± .01^{b}	0.07 ± .01^{b}	0.07 ± .01^{b}	0.10 ± .01^{a}	0.09 ± .00^{a}
cis-10	0.04 ± .00^{b}	0.04 ± .01^{b}	0.04 ± .01^{b}	0.04 ± .01^{b}	0.07 ± .01^{a}	0.06 ± .00^{ab}
Stearic acid	5.26 ±.11^{a}	5.27 ± .02^{a}	5.28 ± .10^{a}	5.05 ± .18^{a}	5.09 ± .04^{a}	5.36 ± .05^{b}
Oleic acid	39.18 ± .24^{c}	41.26 ± .74^{b}	39.18 ± .26^{c}	41.11 ± .10^{b}	41.06 ± .61^{b}	42.93 ± .83^{a}
Linoleic acid	44.62± .16^{ab}	42.73 ± .69^{cd}	44.73 ± .16^{a}	43.05 ± .26^{bc}	43.20 ± .43^{abc}	41.28 ± .83^{d}
Arachidic acid	0.61 ± .04^{a}	0.58 ± .00^{a}	0.60 ± .02^{a}	0.56 ± .02^{a}	0.56 ± .11^{a}	0.58 ± .01^{a}
cis-11-Eicos.	0.17 ± .00^{d}	0.18 ± .00^{cd}	0.18 ± .00^{cd}	0.19 ± .00^{bc}	0.20 ± .01^{a}	0.20 ± .00^{ab}
Linolenic acid	0.19 ± .14^{b}	0.40 ± .01^{a}	0.42 ± .02^{a}	0.44 ± .01^{a}	0.39 ± .021^{a}	0.38 ± .00^{a}
Behenic acid	0.13 ± .00^{ab}	0.13 ± .00^{ab}	0.13 ± .01^{a}	0.12 ± .01^{b}	0.12 ± .00^{ab}	0.12 ± .00^{ab}
Lignoceric a.	0.10 ± .02^{a}	0.09 ± .00^{a}	0.08 ± .00^{a}	0.07 ± .00^{a}	0.08 ± .00^{a}	0.07 ± .01^{a}
Oil yield (%)	18.71±1.35^{c}	27.29±1.76^{ab}	31.18±3.31^{a}	21.85±3.42^{bc}	20.56±0.60^{bc}	22.13±1.91^{bc}

Means±SE in the same row with the same letter are not significantly different from each other according to Duncan's multiple range test (α=0.05)

Table 5. Water- deficit treatments on the mineral content

	Osmanlı cv.			Muganlı-57 cv.		
	C	MWD	SWD	C	MWD	SWD
Ca	27.81±0.39[b]	25.60±1.34[b]	42.39±4.39[a]	36.71±0.36[a]	35.49±1.28[a]	39.66±2.99[a]
K	30.39±0.51[ab]	17.74±1.13[c]	31.31±0.23[a]	30.29±1.52[ab]	29.46±0.96[ab]	28.00±0.11[b]
Mg	24.56±4.54 [a]	17.96±2.35[a]	19.93±0.37[a]	19.23±0.77[a]	18.73±0.73[a]	19.28±0.28[a]
Na	8.71±0.09[ab]	6.77±0.63[b]	8.56±0.37[ab]	8.87±0.14[ab]	8.16±1.35[ab]	9.63±0.18[a]

Means±SE in the same row with the same letter are not significantly different from each other according to Duncan's multiple range test (α=0.05)

Effects of drought on mineral nutrients

Minerals are required to activate vast of enzyme reactions within body. Sustainability of life is dependent upon the body's ability to provide balance between the minerals (Watts 1997; Prasad and Bisht 2011). Increase in frequency and duration of dry periods in arid and semi-arid regions in many parts of world and the problems associated with the water constraints in irrigation systems and areas may affect the bioavailability and mobility of minerals and mineral-nutrient relations in plants (Hu and Schmid 2005).

Crop mineral nutrient performance was considerably affected by severity drought in comparison with in terms of Ca, K, Na contents for Osmanlı cv., as well as K, and Na contents for Muganlı-57 cv. Drought did not elicit crucial impact on Mg content for both cultivars.

Mediating stress response during injury, recovery from injury, and acclimation to stress are reported to be significant roles of Calcium (Ca) by Palta (2000) and Waraich et al. (2011). It has been proposed that Ca is required to induce activation of the plasma membrane enzyme which is necessary to pump back the nutrients that were lost in cell damage Palta (2000). In the present study, the concentration of Ca was highest under SWD conditions in comparison with C and MWD for both cultivars. Calcium enhances the plant growth under drought condition by playing a role as a calmodulin which controls the plant metabolic activities (Waraich et al. 2011).

Potassium is of the osmotic mediating cell expansion and turgor-driven movements and a competitor of Na. For maintaining the turgor pressure, K is essential factor to cope with the unfavorable conditions. Additionally, higher K: Na ratio will improve the resistance of plants exposed to stress conditions (Hu and Schmid 2005). The availability of potassium, in general, decreases with the limiting soil water contents. Herein, the content of K in Osmanlı cv. increased with water deficit treatments whereas it declined with water deficit treatments in Muganlı-57cv. Consequently higher K/Na ratio was obtained in Osmanlı cv. than Muganlı-57cv. Even though in many studies reported, the potassium increases the plant's drought through its physiological functions in stomatal regulation, osmo-regulation, energy status, charge balance, protein synthesis (Marschner 1995), agronomical parameters concerned with yield and quality for both compared cultivars did not statistically differ except capsule number, which decreased with deviation from control group treatment for Osmanlı cv.

In the present study, sodium (Na) concentration in seeds was influenced by water depletion treatments. Highest level was obtained under MWD conditions for Osmanlı cv. whereas the highest concentration was determined under SWD groups for Muganlı-57 cv. Accordingly, Osmanlı cv. developed a better exclusion mechanism for Na once compared to Muganlı-57 cv. It has been generally observed that plants exposed to saline media take up high amounts of Na while the uptake and accumulation of K and Ca are declined. Ca/Na ratios are considered to be important components of its salt tolerance. The maintenance of Ca acquisition and transport under stressful conditions is also important determinant of salinity tolerance (Ashraf and Orooj 2006). Indeed, herein, Ca/Na ratio increased with treatment levels of water deficiency for Osmanlı cv. whereas it decreased under water depletion for Muganlı-57 cv. Accordingly, Osmanlı cv. can be considered more tolerant than Muganlı-57 cv. concerned with Ca/Na ratio. K/Na ratio increased under SWD treatment for Osmanlı cv. whereas it decreased with deviations from field capacity. Even though, it is proposed that the availability of potassium, in general, decreases with the limiting soil water contents. Higher K/Na ratio will improve the resistance of plants exposed to unfavorable conditions (Hu and Schmid 2005).

Magnesium (Mg) is associated with several physiological and biochemical processes in plants influencing growth and development. Mg is involved in activating more enzymes than any other mineral nutrient (Epstein and Bloom 2004; Waraich et al. 2011). For both cultivars compared herein, there was no statistically significant difference among cultivars and treatment groups. Mg increases uptake of water and nutrients by increasing root growth and root surface and it may reduce reactive oxygen species and prevent oxidative damage to chloroplast under drought conditions (Waraich et al. 2011).

CONCLUSIONS

Taken together, the application of drought treatments significantly reduced the plant growth and caused a subsequent decline in capsule number. However, drought did not elicit appreciable changes with seed number, 1000-seed number, seed yield/plant, and seed yield/pot for both cultivars. On the other hand, oil yield of Osmanlı cv. was positively affected with the water deficit treatments. It increased significantly about by 45.88% and 66.66% under MWD and SWD, respectively, in comparison with control. However, oil yield of Muganlı-57 cv. was not significantly influenced with drought. Fatty acid contents for both cultivars varied depending on the degree of water deficit levels. In addition, the large proportions of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) increased with deficit irrigations. Water deficit decreased significantly the proportion of the major saturated fatty acid (SFAs) for Osmanlı cv. the proportion of MUFAs increased with deficit irrigations. PUFAs were not significantly influenced while SFAs reduced under drought for Muganlı-57 cv.

Overall, these results reveal that deficit irrigations tend to increase the degree of unsaturation of sesame seeds. Osmotic regulation is an effective phenomenon for stress tolerance in crop plants. Water depletion disturbs the mineral-nutrient relations in plants through modulating transport and partitions in plants. In this context, tolerance degree is associated with maintenance of ratios between minerals. Herein, Ca/Na ratio increased with treatment levels of water deficiency for Osmanlı cv. whereas it decreased under water depletion for Muganlı-57 cv. Accordingly, Osmanlı cv. can be considered more tolerant than Muganlı-57 cv. concerned with Ca/Na ratio. K/Na ratio increased under SWD treatment for Osmanlı cv. whereas it decreased with deviations from field capacity. Regardless cultivars, Plant height, seed number, 1000-seed weight, seed yield per pot and severe water deficit (Reference: Control) were significant independent variables for Plant seed yield.

Strategic Outlook on Food Security, Disasters and Sustainability

We suggest our findings reported here are worthy of consideration in the current era of drafting the proposed United Nations SDGs that will remain in effect for the 2016-2030 term. Understanding how water deficit and drought impact sesame growth and biochemical correlates, a major foodstuff consumed worldwide and especially in developing countries, is of direct relevance to food security, and by extension, building sustainable and peaceful societies where food insecurities related to water deficit are addressed. Finally, under the above overarching framework, the findings reported here from the Euphrates Valley of the Middle-East in southeast Turkey is particularly important for scholars interested in disasters research as Middle-East is laden with food insecurity and water deficit related conflicts. By better understanding how sesame responds to water deficit, we may be able to anticipate the attendant consequences on food supplies and security and by extension, how best we might be able to contribute and make a difference as global citizens while the United Nations SDGs are coming into effect by 2016.

Conflicts of Interest

The author declare no conflict of interest

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