The Effect of Water Deficit on some Physiological Properties of *Abelmoschus esculentus* (L.) Moench cv. "Sultani"

Murat DEVECI[1,*], Evren CABI[2], Levent ARIN[1], Ozcan YAVAS[1]

[1]Namik Kemal University, Faculty of Agriculture, Department of Horticulture, Tekirdag, Turkey
[2]Namık Kemal University, Faculty of Science and art Sciences, Dept. of Biology, Tekirdag, Turkey
*Corresponding author: muratdeveci@nku.edu.tr

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This study was conducted to determine the some physiological changes after the artificial drought stress in okra (*Abelmoschus esculentus* (L.) Moench cv."Sultani") which is widely cultivated in Turkey and well adapted to Trakya region. After germination, the seedlings were grown under normal growing conditions in an unheated plastic greenhouse until they reached to 2-4 leaf. They were planted in the field with a distance of 50 cm between rows and 25 cm in rows. The plants normally irrigated until flowering time. After then, water constraint applied for drought stress. Control plants were irrigated to bring to field capacity, when they lost 50% of usable water capacity in root region. Other plots were irrigated to 0%, 25% and 50% of applied water in control parcel. Water restriction was done once a week and then measurements were made. During the experiment, leaf water potential (-MPa), leaf relative water content (%), membrane damage in leaf cells (%) and total chlorophyll (SPAD value) in leaves were determined. As results, it has been determined that as the amount of water restriction goes from control to 0%, the leaf water potential decreases and the plants grown at 0% water constraint show severe damage symptoms. It has also been found that the amount of leaf-relative water content and the total amount of chlorophyll are reduced in a manner contrary to the increase in drought stress. Contrary to other criteria, membrane damage and leaf temperatures increase in leaf cells due to the increase in the amount of water restriction.

Keywords: *Abelmoschus esculentus* cv. Sultani, water stress, leaf water potential, leaf relative water content, membrane damage, total chlorophyll

Introduction

As in the whole world, our country has also been affected with the results of global warming such as weakening of water resources, drought, desertification and ecological degradation. Turkey is definitely one of the risky countries in terms of the potential effects of global warming.

Because of the global climate change, arid and semi-arid areas in the world have been expanding continuously. The duration and severity of droughts which can trigger other processes such as salinization and erosion are getting bigger (Turkes, 1997).

One of the continuing problems in crop production is lack of water. Cultivated plants usually require too much water for their growth. Water shortage often leads to significant loss of quality as well as yield losses. The traditional solution to the drought struggle is irrigation. Nowadays, however, qualified water resources are declining and many users, such as farmers, industrialists and municipalities, compete for the same water. Even if the farmers can afford high costs of the irrigation and necessary equipment for irrigation, it is not always a reasonable solution. This conviction is becoming increasingly widespread and there is growing interest in plants that have the capacity to provide good yield under arid conditions (Cirak and Esendal, 2006).

Okra originates from West Africa. It is scientifically named "*Abelmoschus esculentus*" or "*Hibiscus esculentus*" and belongs to the family Malvaceae. In Trakya region, Okra is usually planted in the first week of May and after 57-60 days it can be harvested. Harvest is usually done in the morning hours. After this time, the fruit does not easily pull off and the harvest becomes difficult (Salk et al. 2008).

In our research, physiological morphological and chemical changes brought about by different water constraints in okra cultivation were determined.

Materials and Methods

In this study, Sultani (*Abelmoschus esculentus* L) variety which is well adapted to Trakya Region and widely grown in Turkey was used as material. The test was established in the Edirne-Kesan district. GPS coordinates of the location are follows as 40°52'25.43" N, 26°36'43.01"E.

In the experiment, the okra seeds placed between a moist cloth were soaked for two days. The seeds were planted in multipots and then they were kept in plastic greenhouse without heating until 2-4 leaf seedlings and grown under normal care and irrigation conditions. After then, the plants were planted in experimental area with a distance of 50 cm between the rows and 25 cm above the rows (Salk et al. 2008). Then plants had been given normal water by drip irrigation. We started to apply artificial drought stress after the first flowering period. Control plants were irrigated to bring to field capacity, when they lost 50% of usable water capacity in root region. Other plots were irrigated to 0%, 25% and 50% of applied water in control parcel. Water restriction was done once a week until harvesting period. (Yildirim and Kodal, 1998).

Experimental design was completely randomized block design with 5 replicates. There were 4 different treatments of water deficiency levels and there were 20 plants in each treatment plot.

Statistical analyzes of the data obtained from the experiment were made using the MSTAT version 3.00/EM package program. Significant statistical differences were determined with the L.S.D. control method (Akdemir et al. 1994).

Water restriction was initiated during the first flowering period and after one week from this date, first leaf water potential measurements were started and a total of 6 measurements were made for this purpose. In the last harvest period of the experiment, leaf relative water content, membrane damage in leaf cells and total chlorophyll content were determined by the following methods.

Leaf water potential measurement (-MPa)

Leaf water potential was measured by Scholander Pressure Chamber. The measurements were made 2 hours before (Ψ_{pd}: Pre-dawn leaf water potential) and 6 hours after (Ψ_{md}: Midday leaf water potential) sun rise respectively. The measurements (in 40 atmospheric pressure was using pure nitrogen) were made on most developed leaves of plant (Scholander et al. 1965). They were repeated six times with 1 week intervals after flowering.

Leaf relative water content (RWC) (%)

RWC was calculated by below equation (1) (Sanchez et al. 2004).

$$\mathbf{RCW} = \frac{100(\mathrm{FW}-\mathrm{DW})}{\mathrm{TW}-\mathrm{DW}} \quad (1)$$

FW=Fresh weight, DW= Dry weight, TW= Turgid weight

Membrane damage index (%)

Membrane damage index (MDI) was calculated by measuring the electrolyte released from the cell (Fan and Blake, 1994). In each vegetation period, disks with diameter of 17 mm taking from leaves of stress and control plants were kept in ionized water for 5 hours and then their electricity conductivities (EC) were measured. Same disks were kept in autoclave at 100 °C for 10 minutes and then the EC value of the solution was measured again. The membrane damage in leaf cells (%) was calculated with the help of the below equation (2).

$$\mathrm{MDI} = \frac{100(\mathrm{Lt}-\mathrm{Lc})}{1-\mathrm{Lc}} \quad (2)$$

Lt: EC before autoclaving / EC after autoclaving of the leaf which is under drought stress

Lc: EC before autoclaving / EC after autoclaving of the control leaf.

Determination of total chlorophyll content (SPAD)

The chlorophyll content of the okra leaves was measured by “Konica Minolta SPAD-502” portable chlorophyll-meter. In each period, same readings were made from two regions of the leaf (close to midrib) and from five plants in each parcel (Geravandi et al. 2011).

Results and Discussion

The effects of different water constraints on pre-dawn (Ψ_{pd}) and mid-day (Ψ_{md}) leaf water potentials are shown in Table 1, 2 and Figure 1, 2.

In Figures 1 and 2, the background is colored according to general plant physiology and scale values that many researchers have found in studies of different species (Taiz and Zeiger 2008). Significant differences were found between 0% and control applications on the basis of pre-dawn and mid-day leaf water potential measurements. Initial measurements were made one week after the start of water restriction, and pre-dawn leaf water potential (Ψ_{pd}) values were found to be gradually decreasing when the stress level increases (Table 1 and Figure 1).

During the experiment, Ψ_{pd} values ranged between 0.09 MPa and 2.24 MPa. stress was not determined in control, 50% and 25% irrigation regimes (-0.09, -0.13 and -0.20 MPa), otherwise in the 0% irrigation medium stress conditions were measured (-0.29 MPa).

In the 100% irrigation regime, pre-dawn leaf water potential (Ψ_{pd}) at the 6th week after flowering decreased to -0.24 MPa and remained at the level of low-medium stress. The Ψ_{pd} values after 6 weeks later from the flowering time showed that okra plants are at a severe stress levels (-0.78, -1.26 and -2.24 MPa) in 50%, 25% and 0% irrigation plots (Table 1 and Figure 1).

Table 1. The effect of different water constraints on the mean values of pre-dawn leaf water potential (-MPa)

Water Deficiency Level	Number of weeks after flowering					
	1	2	3	4	5	6
% 0	-0.29	-0.58	-1.26	-1.76	-1.96	-2.24
% 25	-0.20	-0.43	-0.57	-0.81	-1.14	-1.26
% 50	-0.13	-0.28	-0.33	-0.48	-0.65	-0.78
% 100 (Control)	-0.09	-0.11	-0.13	-0.17	-0.23	-0.24

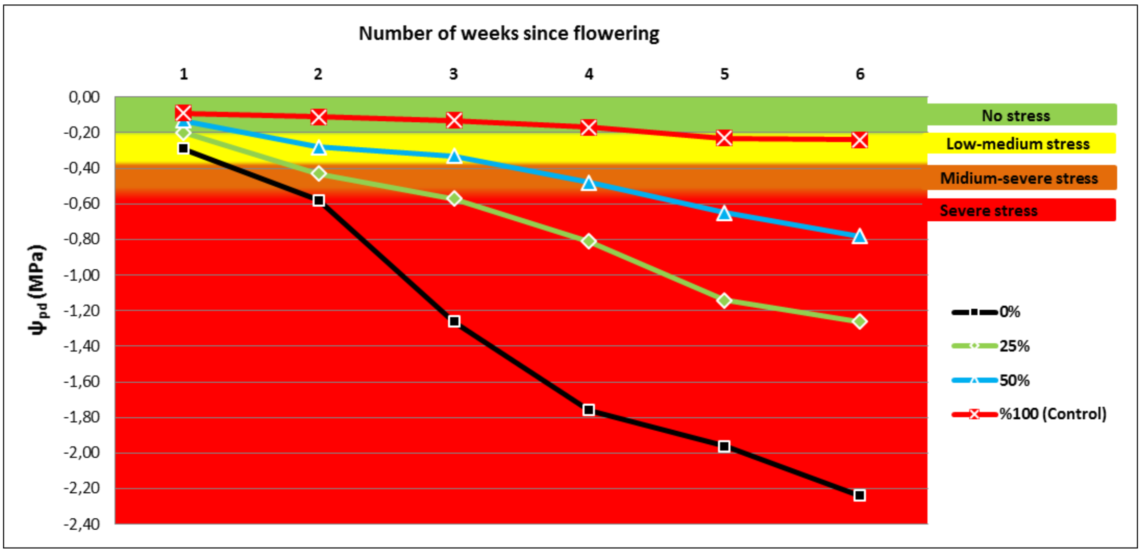

Figure 1.The effect of different water constraints on the mean pre-dawn leaf water potential (-MPa).

It was determined that the mid-day leaf water potentials (Ψ_{md}) tend to decrease gradually and the stress level increases accordingly (Table 2 and Figure 2).

According to first mid-day leaf water potential values (Ψ_{md}) which were measured after 1 week from the start of water restrictions, it was observed that control, 50% and 25% irrigation regimes had no stress (-0.48, -0.66 and -0.93 MPa), otherwise the Ψ_{md} value (-1.13 MPa) in the first measurement in the 0% parcel where no irrigation was performed remained under the low stress conditions. In parallel with the continuation of the stress conditions, in the control application values were observed in the low stress zone (-1.01 MPa), 25% in the high stress zone (-1.45 MPa) and in the severe stress zone (-2.39 and -3.16 MPa)

As a result of stress conditions, control were in the low- stress region (-1.01 MPa), 50% treatment was in high stress region (-1.45 MPa), 25% and 0% treatments were in severe stress (-2.39 and -3.16 MPa) region (Table 2 and Figure 2).

Table 2. The effect of different water constraints on the mean values of mid-day leaf water potential (-MPa)

Water Deficiency Level	Number of weeks after flowering					
	1	2	3	4	5	6
% 0	-1.13	-1.52	-1.89	-2.37	-2.54	-3.16
% 25	-0.93	-1.17	-1.26	-1.79	-2.03	-2.39
% 50	-0.66	-0.72	-0.98	-1.18	-1.29	-1.45
% 100 (Control)	-0.48	-0.6	-0.68	-0.76	-0.91	-1.01

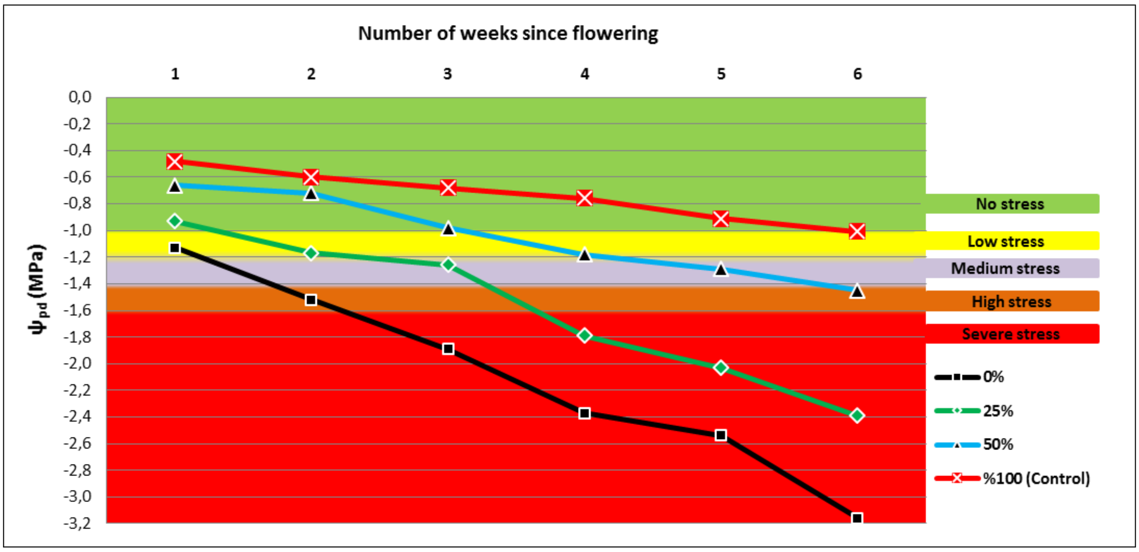

Figure 2. The effect of different water restraints on the mid-day leaf water potential (-MPa).

Deveci and Uyan (2011) stated that spinach plant has the highest amount of water at the harvesting period. So the most water is needed to sustain its activities in that period. They also added that water stress will occur in this period, As result, only control and 75% irrigation group plants were not affected, but 0%, 25% and 50% irrigation group of the plants were not able to survive agains the stress. Kucukkomurcu (2011) who was studied on the screening of okra genotypes for tolerance to salinity and drought stresses stated that, the damage to the cell is more pronounced than in drought stress conditions. Deveci and Celik (2016) determined that the leaf water potential was reduced due to the decrease in irrigated water by up to time from sowing to blossoming in the ground cherry According to this, while the lowest leaf water potential was obtained from the water restriction increased, the leaf water potential increased as the irrigation rate increased.

Mean values of the leaf-relative water content (LRWC) measured in this study are given in Table 3. There appears to be a direct relationship between the different watering rates applied to the plants and the leaf-proportional water content (Table 3). The leaf-proportional water content has been found to fall in parallel to the water restrictions imposed on the plants. The greatest decrease in leaf-proportional water content was seen at 0% water restraints. The control group has the highest leaf-relative water content (98.11%).

In the studies dealing with drought and salinity carried out by Kucukkomurcu (2011) in okra , Kaya and Higgs (2003) in pepper, Tuna et al. (2010) in melon, Turkan et al. (2005) in pea, water stress significantly reduced leaf-proportional water content and vegetative growth. The result of our study was similar to those of researchers working with different plants.

Table 3 and Figure 3 shows that the membrane damage of leaf cells varies between 0.34% and 22.83% depending on the water stress levels. While the lowest value was obtained from the control application, plants grown without irrigation had the highest value.

Arslan (2011) stated that tissue membrane permeability is an expression of the ability of plants to maintain membrane integrity under stress. As a result of cell membrane damage of the plants grown under stress conditions, the water-soluble substances migrate into intercellular spaces, which increase the tissue electrical conductivity value. So it is known that there is an inverse relationship between tissue electrical conductivity values and membrane integrity. Kucukkomurcu (2011) reported that in the okra leaves had damage at different proportions resulted in drought. Deveci and Celik (2016) and Kaya and Dasgan (2013) reported that decreases in water use increased electrolyte leakage.

The total chlorophyll amount of okra plants which are grown under different water constraints and the statistical significance rankings of these averages are shown in Table 3 and Figure 3. I, the highest total chlorophyll amount was obtained from the control application (55.76 SPAD) and the lowest total chlorophyll amount was found in 0% application (31.02 SPAD)

Table 3. Effect of different water restraints on leaf-relative water content (%), membrane damage index (%) and total chlorophyll content (SPAD) and groups according to LSD test*

	Water constraint Levels			
	% 0	% 25	% 50	% 100
Leaf relative water content (%)	47.58 d	59.35 c	77.74 b	98.11 a
Membrane damage index (%)	22.83 a	5.85 b	1.24 b	0.34 b
Total chlorophyll content (SPAD)	31.02 d	37.48 c	44.56 b	55.76 a

*There is no difference between the averages carrying the same letter as 0.01

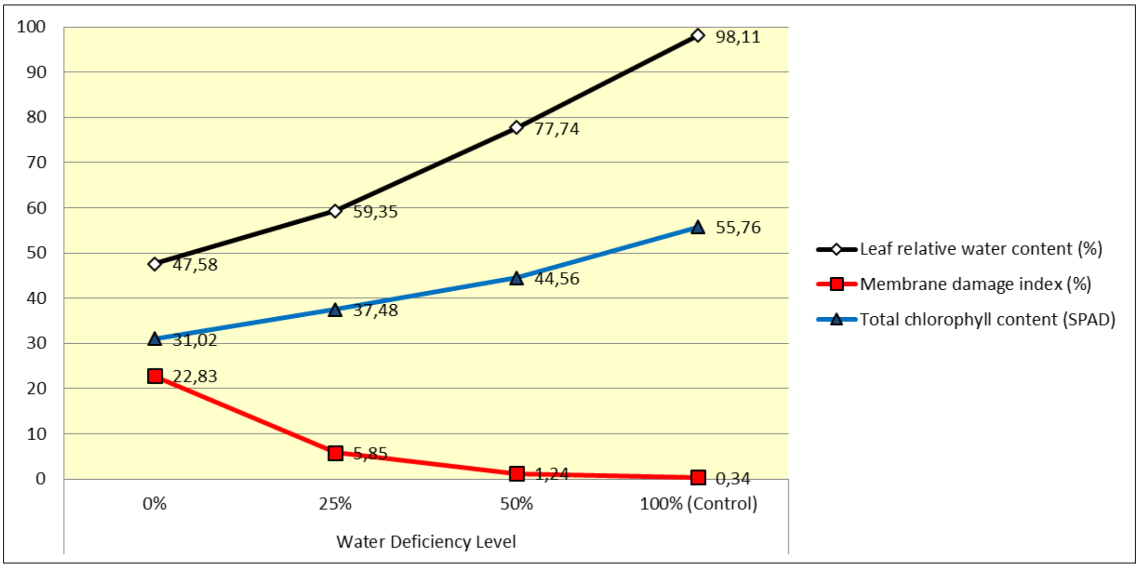

Figure 3.Effect of different water restraints on leaf-relative water content (%), membrane damage index (%) and total chlorophyll content (SPAD) of okra plants

It has been found that the total chlorophyll amount decreases with increasing water stress compared to the control application. Reductions in the amount of chlorophyll with water stress are generally caused by the damage of the chlorophyll membranes (Yagmur, 2008). Changes in the total amount of chlorophyll are consistent with the findings of other investigators (Deveci and Celik 2016).

Conclusions

As results, it has been determined that as the amount of water restriction goes from control to 0%, the leaf water potential decreases and the plants grown at 0% water constraint show severe damage symptoms. It has also been found that the amount of leaf-relative water content and the total amount of chlorophyll are reduced in a manner contrary to the increase in drought stress. Contrary to other criteria, membrane damage increased when the amount of applied water was decreased.

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