The effects of different water deficiency on physiological and chemical changes in Cape gooseberry (*Physalis peruviana* L.) which were grown in greenhouse conditions

M. Deveci, A. Celik

Department of Horticulture, Faculty of Agriculture, Namik Kemal University, Tekirdag, Turkey

**Abstract**

*Physalis peruviana* L. was used in this research. The experimental design was randomized block with 4 replications and 5 water application (control, 0%, 25%, 50% and 75%) the experiment was made in a cold greenhouse to avoid the risk of rain in open. During the experiment, leaf water potential (MPa), membrane damage on the leaves (%), leaf temperature (°C), total phenolic matters (mg/100g) and total chlorophylls (mg/l) in the leaf were measured. According to the results, the control application gave less total chlorophylls (41.23 mg/l) and total phenolic matters (285.77 mg/100g). As the water level decreased, membrane damage on the leaves (% 76.36) and leaf temperature increased and the levels were the highest in the 0% water deficit. The stress of water affected badly the growth and development of the Golden Berry. It was found that the plants were given 100% water (control) and 75% water level were not affected by water stress but 0%, 25% and 50% water level applied plants could not overcome the stress and could not sustain the growth and development.

**Key words:** Cape gooseberry, leaf water potential, membrane damage on the leaves, total phenolic compounds, total chlorophyll content

**Introduction**

Yield reduction occurs in agricultural areas with the effect of stress factors such as minerals, low temperature, frost and especially drought (Blum, 1986). For this reason, development of plant genotypes which can resist or tolerate these stress factors is required.

In cases when water resources are limited or their cost is high, limited irrigation programs, which allow taking more advantage of unit water, instead of normal irrigation. Accordingly it is possible to perform irrigation in a wider area with the existing irrigation water (Maleki and Reza, 2012).

According to various climate models it has been foreseen that Turkey, which has a mixed climate structure, will be drastically affected from a climate change which may take place depending on global warming as of 2030’s, that majority of the country will be under the effect of dry and hot climate and that it will be significantly affected in terms of water resources, ecological and economical processes, ecosystem and bio-variety and agriculture. *Physalis peruviana* L (*P. edulis* Sims) which is generally known as Cape gooseberry species are known in various countries of the world with different names. Almost all of the species cultivation of which are performed belong to this species (Fischer et al., 2011). Cape gooseberry (*Physalis peruviana* L.) is a medical plant which is widely used in treatment of cancer, malaria, hepatitis, dermatitis and rheumatism (Wu et al., 2005). Its fruits have important place among diabetic and low calorie products (Ramadan and Moersel, 2007). Cultivation of Cape gooseberry which is widely traded in many countries started to increase in Turkey as well in recent years.

The aim of this study is to determine the physiological, morphological and chemical changes that may occur due to various water deficiencies.

**Materials And Methods**

**Plant material and experimental design**

The research was carried out in the polyethylene greenhouse condition of the Horticulture Department, Faculty of Agriculture, Namik Kemal University, Tekirdag, Turkey (40°59′ N, 27°29′ E and 4 m altitude) in the between May 2011 and October 2011.

In this research a Cape gooseberry species named Gamerika01, which is most probably originated from a standard species and which is widely found in the market (Klinac, 1986), was used as a material.

The environment where the plants were cultivated; was selected as a non-heated plastic greenhouse due to unexpected rain risk on cape gooseberry which is normally cultivated in open terrain. The seedlings were provided from

---

**Paper Information**

Received: 19 January, 2016

Accepted: 11 March, 2016

Published: 30 April, 2016

**Citation**

general directorate of rural services Menemen research institute. The seedlings were planted in their original locations in the greenhouse with distances of 150x60cm instead of suggested 1x1m distance (Salazar et al., 2006), so as to minimize the underground root interaction during irrigation. While irrigation water was supplied to control parcels so as to allow water deficiencies to increase the existing moisture to the field capacity when 50% of the usable water holding capacity in plant root section, 0%, 25%, 50% and 75% of the irrigation water supplied to control parcels was supplied to other parcels (Koksal et al., 2010). Fruits were harvested at harvest maturation period from capegooseberry plants cultivated in non-heated greenhouse environment and accordingly measurements, counting and observations were made.

The experiment was conducted on clayey loam soil. Some of the chemical properties of soil determined in the laboratory are given in Tables 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Result</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>7.64</td>
<td>Saturation</td>
</tr>
<tr>
<td>Salt</td>
<td>(%)</td>
<td>0.06</td>
<td>Saturation</td>
</tr>
<tr>
<td>Lime</td>
<td>(%)</td>
<td>2.46</td>
<td>Calcimetry</td>
</tr>
<tr>
<td>Structure</td>
<td>(%)</td>
<td>59.00</td>
<td>Saturation</td>
</tr>
<tr>
<td>Organic matter</td>
<td>(%)</td>
<td>1.06</td>
<td>Walkey-Black</td>
</tr>
<tr>
<td>Total nitrogen (N)</td>
<td>(%)</td>
<td>0.05</td>
<td>Kjeldahl</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>(ppm)</td>
<td>73.90</td>
<td>Olsen-ICP</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>(ppm)</td>
<td>290.36</td>
<td>A. acetate-ICP</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>(ppm)</td>
<td>5.194.97</td>
<td>A. acetate-ICP</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>(ppm)</td>
<td>432.07</td>
<td>A. acetate-ICP</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>(ppm)</td>
<td>8.05</td>
<td>DTPA-ICP</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>(ppm)</td>
<td>1.45</td>
<td>DTPA-ICP</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>(ppm)</td>
<td>1.33</td>
<td>DTPA-ICP</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>(ppm)</td>
<td>4.05</td>
<td>DTPA-ICP</td>
</tr>
</tbody>
</table>


Evaluation of data

The experiment was established as a factorial randomized block design with four replications and 5 different irrigation applications (100% irrigation (control), 75% irrigation, 50% irrigation, 25% irrigation and 0% irrigation) were used in each replication. In all the experiments; 20 parcels in total and 20 plants for each parcel were used. Data were subjected to analysis of variance, with factorial comparisons of main effects and interactions. Means were tested by protected LSD (at the 0.01 level). MSTAT 3.51 was used for analysis of variance (Açıkgöz 1984).

Leaf water potential measurement (MPa)

Leaf water potential was measured by Scholander Pressure Chamber. The measurements were made 6 hours after ($\Psi_{md}$: 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). The measurements were repeated 3-24th day between with 3 days intervals after flowering.

Leaf relative water content (RWC) (%)

In trials related with resistance to drought. Studies of researchers working on various plants about leaf relative water content (RWC) (Sanchez et al. 2004). At the end of stress fresh weights of the plants (FW) were taken in order to determine the relative water contents. After that the leaves were kept in pure water for 4 hours and during this period their turgid weights (TUW) were calculated. The weight samples weights of which were determined were dried in stove at 65 °C for 48 hours and then dry weight (DW) was measured in grams. The ratios of obtained fresh and dry weights were calculated by below equation (1) in order to find leaf relative water contents (%).

$$\text{RCW} = \frac{100 (\text{FW} - \text{DW})}{\text{TW} - \text{DW}}$$  \hspace{1cm} (1)

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 17mm were taken 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. From the obtained value the membrane damage in leaf cells (%) was calculated with the help of the below equation (2).

$$\text{MDI} = \frac{100 (\text{Lt-Lc})}{1-\text{Lc}}$$  \hspace{1cm} (2)
Measurement of Leaf Temperature (°C)
Infrared thermometer technique which is based on measuring plant surface temperature allows faster and more precise measurement without touching the plant. The mentioned technique is based on transpiration which decreases the leaf surface temperature. In the measurements infrared thermometer having filters which detects rays at a wavelength of 7-18 nm (IRT) (Raynger ST8 model) were used (Erdem et al., 2010).

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

Determination of total phenolic compound (mg/100 g)
The amount of phenolic compounds existing in spinach extracts was determined by using Folin Ciocalteu colorimetric method. 0.5 g of plant material was collected from the plant’s leaf tissues and it was omogenized in 5 mL of 0.1M phosphate buffer. The homogenate was centrifuged for 10 min at 12,800 rpm. Then, 2 mL was drawn from the solution and 3 % sodium carbonate and 0.3 N Folin-Ciocalteau were added to the sample until the final volume of 4 mL. Then, the solution was kept for 1 h at room temperature. Measurements with in spectrophotometer were conducted at a wavelength of 765 nm. The results were calculated by using the concentrations in the gallic acid standard (Chantiratikul et al., 2009).

Results And Discussion
Leaf water potential (MPa)
In leaf water potential examination the effect of different water deficits on Cape gooseberry at in the midday ($\psi_{md}$) leaf water potential were shown in Table 2 and Figure 1.

In leaf water potential examination, as a result of water deficiencies which began to be applied in the beginning of flowering period, the leaf water potential value was determined to vary between $-2.45$ and $-0.42$ MPa.

Table 2. Effect of different water deficiency levels on average midday ($\psi_{md}$) leaf water potentials in Cape gooseberry (MPa)

<table>
<thead>
<tr>
<th>Water deficiency</th>
<th>0</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>15</th>
<th>18</th>
<th>21</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>% 0</td>
<td>-0.42</td>
<td>-0.87</td>
<td>-0.90</td>
<td>-1.60</td>
<td>-1.77</td>
<td>-2.30</td>
<td>-2.37</td>
<td>-2.45</td>
</tr>
<tr>
<td>% 25</td>
<td>-0.44</td>
<td>-0.80</td>
<td>-0.82</td>
<td>-1.50</td>
<td>-1.63</td>
<td>-2.03</td>
<td>-2.20</td>
<td>-2.23</td>
</tr>
<tr>
<td>% 50</td>
<td>-0.46</td>
<td>-0.77</td>
<td>-0.77</td>
<td>-1.33</td>
<td>-1.62</td>
<td>-1.80</td>
<td>-1.93</td>
<td>-1.95</td>
</tr>
<tr>
<td>% 75</td>
<td>-0.47</td>
<td>-0.57</td>
<td>-0.63</td>
<td>-0.69</td>
<td>-0.97</td>
<td>-1.09</td>
<td>-1.21</td>
<td>-1.34</td>
</tr>
<tr>
<td>% 100</td>
<td>-0.42</td>
<td>-0.55</td>
<td>-0.59</td>
<td>-0.63</td>
<td>-0.80</td>
<td>-0.96</td>
<td>-1.03</td>
<td>-1.08</td>
</tr>
</tbody>
</table>

Figure 1. Effect of different water deficiency levels on average midday ($\psi_{md}$) leaf water potentials in Cape gooseberry (MPa).
In our research it was determined that leaf water potential decreased due to reduced irrigation during the time passed from flowering to harvest. Accordingly it was observed that lowest leaf water potential was achieved as water deficiency increased while leaf water potential averages increased as irrigation ratio increased. In the first measurement performed 3 days after the start up of water deficiency it was determined that no difference occurred between irrigation regimes (-0.47, -0.42 MPa) and stress also did not occur as observed in figure 1. Differences between leaf water value started to occur 9 days after flowering and did not decrease below the threshold (-1MPa) limit and determined that none of the irrigation subjects exceeded stress threshold.

Stress conditions started 12 days after flowering and while 0% and 25% irrigation regimes caused high stress in this period (-1,60, -1,50 MPa), 50% irrigation stress remained within the medium stress conditions. 15 days after flowering while serious stress occurred in cape gooseberries to which 0%, 25% and 50% irrigation was applied (-1,77, -1,63 ve -1,62 MPa), it was observed that cape gooseberries which were cultivated at 100% and 75% irrigation conditions did not exceed the stress threshold. (-0.97, -0.80 MPa) In day 24 which was the final measurement date, it was observed that middle of the day leaf water potentials (MODLWP) of cape gooseberries which were cultivated with 100% irrigation was observed to be at low stress level (-1,08 MPa) and that MODLWP values were at medium stress level in 75% irrigation conditions. (-1,34 MPa) It was also observed that serious stress conditions increasingly continued in 0%, 25% and 50% irrigation conditions.

Ashraf et al. (2005) determined that leaf water potential decreased due to drought while Karipçin (2009) determined that leaf water potential negatively increased by increasing water level, in other words, leaf water potential increased by increasing stress conditions.

Measurement of Leaf Temperature (°C)

Mean leaf temperature (°C) was measured in pre-dawn and midday by infrared thermometer before each irrigation application without touching the leaves from beginning of water limitation till harvest period were shown in Table 3 and Figure 2.

<table>
<thead>
<tr>
<th>Water deficiency</th>
<th>The number of days after flowering (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% 0</td>
<td>30.6, 30.6, 30.3, 28.5, 30.4, 30.1, 29.9, 26.7</td>
</tr>
<tr>
<td>% 25</td>
<td>30.3, 30.4, 30.5, 28.1, 30.3, 29.6, 29.3, 26.3</td>
</tr>
<tr>
<td>% 50</td>
<td>29.9, 30.1, 28.9, 27.6, 29.9, 28.9, 29.0, 25.9</td>
</tr>
<tr>
<td>% 75</td>
<td>29.6, 29.8, 28.4, 26.9, 28.3, 28.4, 28.5, 25.3</td>
</tr>
<tr>
<td>% 100</td>
<td>29.1, 29.3, 28.2, 26.5, 28.7, 27.9, 28.2, 24.8</td>
</tr>
</tbody>
</table>

Figure 2. Effect of different water deficiency on midday leaf temperature (°C) of Cape gooseberry plant

As seen in Table 3 while highest value in leaf temperatures were measured in 0% application middle of the day measurements, lowest value was measured in control application. Walker and Hatfield (1979) stated that if the increase in plant surface temperature is higher compared to air temperature is asign of water stress of the plant. According to Jackson et al., (1986), when plant surface temperature which was measured radio-metrically was compared with a reference temperature (air temperature) it is an important indication related with water stress.
Leaf relative water content (%)  
It was understood that the effect of irrigation subjects on leaf relative water contents was significant at a level of 1%. The effects of different water restrictions on leaf relative water content can be observed in Table 4. It is observed that there is a direct relation between applied water amounts and leaf relative water content. It was determined that leaf relative water content decreases in parallel with the water deficiencies applied to plants. The greatest decrease in leaf relative water content was observed in 0% subject. 100% subject had to highest leaf relative water content (79.22%). The reason of decrease in leaf relative water content may be that there are non-useful water in the soil or roots may not fulfill the lost water originated from the perspiration due to decrease in absorbing surface (Gadallah, 2000). Tuna et al. (2010) stated that water stress decreased the leaf relative water content while Kirnak et al. (2001b) stated that water stress significantly decreased leaf relative water content (LRWC) and vegetative development.

Membrane damage index (%)  
In the trial, according to the result of statistical analysis performed in terms of membrane damage in leaf cells of capegooseberry plants, main irrigation effect was found to be significant at a level of 1% (Table 4). As it can be understood from the examination of Table 4 in terms of membrane damage in leaf cells the values varied between 8.14% and 76.36%. While lowest value was obtained from control application (8.14%) highest value was obtained from the 0% application in which no irrigation was made. Chen et al., (1991) stated that the decrease in chlorophyll concentrations (due to defoliation) was related with increased electrolyte leakage.

Total chlorophyll content (SPAD)  
Regarding the Gamerika01 Cape gooseberry which was exposed to various water deficiencies, total chlorophyl amount averages and the statistical significance sequence of these averages were shown in Table 4. As seen in Tables 4, while no statistical difference could be observed between 0% and 25% applications, significance level of all other applications were determined to be 1%.

When we examine the effect of irrigation water deficiencies in terms of total chlorophyl amount, while averages varied between 26.60 mg/l–41.23 mg/l, 41.23mg/l was obtained from highest total chlorophyl amount control application and lowest total chlorophyl amount was obtained from 0% application (26.60 mg/l ). It was determined that total chlorophyl amount decreased by increasing water stress compared to control application (Chartzoulakis et al., 1993). These results are in accordance with findings of other researchers. Kirnak et al., (2001) stated that water stress applications decreased dry matter and chlorophyl content and that water stress has inverse effect on chlorophyl concentration.

Total phenolic compound (mg/100 g)  
Regarding the Gamerika01 Cape gooseberry which was exposed to various water deficiencies, total phenolic matter amount averages and the statistical significance sequence of these averages were shown in Table 4. As seen in Tables 4, while no statistical difference could be observed between 0% and 25% applications, significance level of all other applications were determined to be 1%. When we examine the effect of irrigation water deficiencies in terms of total chlorophyl matter amount, while averages varied between 148.50mg/100g–285.77mg/100g, highest phenolic matter amount was obtained from control application (285.77 mg/100g ) lowest total chlorophyl amount was obtained from 0% application (148.50 mg/100g ).

Catalina et al., (2008) determined the total soluble phenolic compound content of Physalis species as 87 ± 19mg GAE/100 g.

Table 4. Effect of different water deficiency levels on average leaf relative water content (%), membrane damage index (%) total chlorophyll content (SPAD) and total phenolic compound (mg/100 g) of Cape gooseberry plant and LSD groups*

<table>
<thead>
<tr>
<th></th>
<th>100% (control)</th>
<th>0%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf relative water content (%)</td>
<td>79.22 a</td>
<td>40.79 d</td>
<td>48.79 d</td>
<td>53.20 c</td>
<td>69.48 b</td>
</tr>
<tr>
<td>Membrane damage index (%)</td>
<td>8.14 e</td>
<td>76.36 a</td>
<td>69.34 b</td>
<td>47.10 c</td>
<td>38.45 d</td>
</tr>
<tr>
<td>Total chlorophyll content (SPAD)</td>
<td>41.23 a</td>
<td>26.60 d</td>
<td>26.62 d</td>
<td>32.90 c</td>
<td>37.55 b</td>
</tr>
<tr>
<td>Total phenolic compound (mg/100 g)</td>
<td>285.77 a</td>
<td>148.50 d</td>
<td>160.29 d</td>
<td>197.55 c</td>
<td>250.66 b</td>
</tr>
</tbody>
</table>

*There is no difference in the level of 0.001 among averages that have the same letter.

Conclusions  
As a result of the water deficiency applied to Cape gooseberry; it was determined in our research that leaf water potential decreased due to decrease in irrigation from flowering period till harvest. Accordingly while lowest leaf water potential was obtained as water deficiency increased, it was observed that leaf water potential averages increased by increasing irrigation ratio. It was determined that after a water stress occurred, only control group and the group to which irrigation was applied with a ratio of 75% were not effected by stress or effected at a low level, but that the plants in 0%, 25% and 50% could not resist the stress.

When the values obtained from the trial were examined, decrease occurred in total chlorophyl and phenolic matter amounts of Gamerika01 Cape gooseberry as a reaction to the water deficiencies achieved by decreasing the water amount given to control application at certain ratios.
It was determined that the amounts of these materials decreased ad irrigation ratio decreased. On the other hand while membrane damage ratio and leaf surface temperatures were observed to be lowest in control irrigation groups which we accept as 100% irrigation groups, increases occurred in the values obtained after reduced irrigation and these criteria reached to highest level in 0% water deficiency application in which irrigation is not applied at all.

References
265