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PHOTOSYNTHESIS ACTIVITIES OF MELON CULTIVARS UNDER FLOODING ENVIRONMENT

Musa Seymen[1*], Havva Nur Kıratlı[2], Bilal Acar[3]
[1*] Department of Horticulture, Faculty of Agriculture, University of Selcuk, Konya/Turkey
[2] Department of Horticulture, Institute of Science, University of Selcuk, Konya/Turkey
[3] Department of Farm Buildings & Irrigation, Faculty of Agriculture, University of Selcuk, Konya/Turkey
* *Correspondence author. E-mail*: mseymen@selcuk.edu.tr

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ABSTRACT

Flooding is such a stress factor leading to reduction in both the yield and quality of crops. One practical solution lowering yield and quality performances of crops in areas with flooding risks is to practice of tolerant plant cultivars. The major purpose of the present work was to identify the most suitable cultivars within 11 different Kırkağaç melon cultivars in accordance of photosynthesis activities. In such pot experiment, all treatments were irrigated with same amount of water during stages of seed sowing-initial of stress applications, and 10-day stress was applied to treatments having the flooding stress in time with plants having four-five leaves. In plants, harvested just after stress application, leaf temperature, stomata conductivity, quantum yield of photosynthesis, and photochemical yield of photosystem II were examined. In results, flooding stress had no significant effects on leaf temperature and stomata conductance but resulted important reductions in quantum yield of photosynthesis, and photochemical yield of photosystem II. There were observed changes among cultivars, and Sürmeli F1 (V-5), Kırkağaç local cultivar (V-10) and Kyrgyzstan local cultivar (V-11) performed maximum photosynthesis activity.

INTRODUCTION

As known that changes of environmental conditions have specific impact on plant growth and development. Those could have some negative effects for crop development leading to stressful conditions. There are number of abiotic stress factors such as flooding, salinity, deficiencies in mineral availability, drought, as well as maximum or minimum temperatures (Teklić et al. 2021). Those factors have become a factor restricting many activities and reduce agro-productivity by negatively affecting plant quality. In addition, biotic and abiotic stress factors have also limitation on plant performance (Seymen 2021; Yavuz et al. 2020; Yavuz et al. 2022; Seymen et al. 2022; Seymen et al. 2023; Yavuz et al. 2023). According to FAO, more than 95% of the world's farm lands are affected adversely from abiotic stress factors. As known, reductions of up to 50-70% in crop yields are resulted from abiotic stress in many cases (Mittler 2002). Increase negative effects of global warming will cause more frequent rises in flooding cases and it is estimated that those negative effects will continue to be witnessed more in agriculture. Today, floods affect 10% of the existing cultivated lands, thus it has become one of the important limitations in agro-production. Yield losses associated by flooding vary from 15% to 80% depending on plant type, soil characteristics, and duration of stress (Patel et al. 2014; Seymen 2021). Flooding stress may lead to remarkable damages to the physiological and growth processes of plants. One of the reasons for the rooting systems of the plant being without oxygen is flooding. Decreased root respiration is the leading response of plants under oxygen deficiency (Rajhi 2011; Akhtar & Nazir 2013). Oxygen deficiencies in that way cause energy-dependent formations such as ion uptake resulting poor roots to form and root growth to stop. Plants try to respond by differentiating metabolic enzymes in their structures to cope with such stress (Greenway et al. 2006). Photosynthesis is the basis for the energy production of plants, and almost 95% of the dry matter of plants is obtained directly from photosynthesis (Zhang et al. 2018). Flooding stress notable reduces carbon assimilation capacity of photosynthesis in plants (Ahmed et al. 2002). Under flooding stress, chlorophyll synthesis is suppressed by limiting adsorption of light energy in plants. By the reduction of CO_2 uptake, stomata close (Ashraf & Arfan, 2005), transport of photosynthetic products reduces (Ushimaru et al. 1995), and over energy consumption occurs (Huang et al. 2008). In addition, flooding stress damages structure of leaf cells and decreases activity of photosynthetic enzyme and PSII reaction centre (Seymen et al. 2022). Researchers report that damage to the photosynthetic apparatus of the plant mainly occurs at PSII locations (Mathur et al. 2014). Many studies have reported that photosynthesis is adversely affected under flooding conditions (Zhang et al. 2018; Wang et al. 2019; Seymen et al. 2022; Seymen et al. 2023).

Melon (*Cucumis melo*) is known a type of vegetable having a pleasant smell and taste and also has many health benefits. It is cultivated widely in many regions. Melon is among the vegetable species which is sensitive to the flooding stress. In that context, flooding stress occurring in areas with heavy rainfall negatively affects yield, restricts growth and development, and even results the death of plants. In this current study, therefore, it was aimed to research the best tolerant melon cultivars by assessing changes in photosynthesis activities under flooding stress conditions for 11 different ‘Kırkağaç’ melon varieties.

MATERIAL AND METHODS

The study was performed in glass greenhouse and laboratories as a pot experiments at Department of Horticulture, Faculty of Agriculture, University of Selçuk during periods September 8- November 1, 2022. Plastic pots with top diameter of 16 cm, a bottom diameter of 14 cm and a height of 13 cm were used in study. An unperforated bag was placed in the pots to create flooding stress. In the experiment, 2.1 kg of air-dry soil was placed in each of the plots. Eleven different commercial melon cultivars, the most common in the market, were used as plant material. Those commercial cultivars, Kırkağaç type winter melon, were as follows; Sarı F1 (V-1), Damla F1 (V-2), Yücel F1 (V-3), 1071 F1 (candidate) (V-4), Sürmeli F1 (V-5), Westeros F1 (V-6), Kırkağaç 637 (V-7), Kırkağaç 589 (V-8), named with the trade names of Süper Soykan (V-9), Kırkağaç local cultivar (V-10), and Kyrgyzstan local cultivar (V-11). In this study establishing according to the randomized plots trial design with three replications, two irrigation regimes were formed: one is full irrigation (I100) and one is water stress treatment (flooding stress-FS). Same amount of water was applied to all pots just following to the seed sowing processes and soil moisture content was reached up to the field capacity (FC). The amount of irrigation water applied to the pots was determined in accordance of soil moisture monitoring by gravimetrically. For that purpose, when the available water capacity of control (I100) subject considered as witness treatment consumed 40-45%, irrigation was done and the soil moisture content reached to the field capacity in each irrigation event by this way. Flooding stress subjects and full irrigation treatments were all irrigated equally (calculated water amount) until stress was established. On October 10, flood was applied to the flooding stress treatments and normal calculated water was given to the full irrigation subjects. Flooding stress was applied to the melon cultivars for 10-day duration (Seymen et al. 2022).

By using LI-COR brand LI-600 fluorimeter device between 9.30-10.30 am in the morning in cloudless conditions, leaf temperature (^{o}C), stomata conductivity (GSW), quantum yield of photosynthesis (QPII) was measured, and in dark-adapted leaves, photochemical efficiency Fv/Fm were determined (Mathobo et al. 2017).

The data obtained from melon cultivars under full irrigation and flooding conditions were statistically evaluated with One-Way Analysis of Variance (ANOVA) in SPSS Statistical program, and the significant differences among the treatments were divided into groups according to the importance levels of 5% and 1% by applying Duncan multiple comparison test.

RESULTS AND DISCUSSIONS

The effects of flooding stress applied to the different melon cultivars on leaf temperature were found insignificant statistically (Table 1). In examined Table 1, average leaf temperature was 19.06 ^{o}C in different melon cultivars under full irrigation conditions, and 19.18 ^{o}C in varieties exposing flooding stress. In examined Variety X Stress interactions, there was no significant difference. Leaf temperature rised under abiotic stress conditions and is one of the important indicators of stress.

Table 1

Effect of flood stress on leaf temperature of melon cultivars (^{o}C)

Varieties (V)	Full Irrigation (I_{100})	Flooding Stress (FS)	Average
V-1	18.75	19.04	18.89
V-2	19.27	19.93	19.60
V-3	18.67	19.44	19.05
V-4	19.51	19.23	19.37
V-5	18.71	19.35	19.03
V-6	18.51	19.19	18.85
V-7	19.68	19.14	19.41
V-8	18.69	19.01	18.85
V-9	18.63	19.53	19.08
V-10	19.50	18.59	19.05
V-11	19.74	18.54	19.14
Average	19.06	19.18	
LSD: 5%* and 1%** **V:** 0.73 $^{n.s.}$ **FS:** 0.31 $^{n.s.}$ **VxFS:** 1.04$^{n.s.}$			

*: Significant at 5%; **: Significant at 1%; and n.s: Not significant

In many studies, leaf temperature increased under stress conditions (Vermeulen et al. 2007; Al-Yasiet et al. 2020; Balfagón et al. 2022). In our study, although there was an increment in leaf temperature in overwatering stress treatments compared to full irrigation treatments, but it was not a significant difference. The not availability of difference in leaf temperature is possibly thought to be due to the leaf structure of the species and cultivars.

The effects of excess water stress applied to different melon cultivars on stomatal conductivity (GSW) were found to be statistically significant (Table 2). In such Table 2, stomatal conductivity was determined as 0.15 mol m^{-2} s^{-1} on average under full irrigation conditions while it was 0.16 mol m^{-2} s^{-1} on the melon cultivars exposed flooding stress. The maximum average GSW as 0.19 mol m^{-2} s^{-1} was obtained from the V-3 melon cultivar. When Variety X Stress interaction examined, statistically significant difference was found, and the highest GSW values were measured from V_1xI_{100} (0.18 mol m^{-2} s^{-1}), V_3xI_{100} (0.19 mol m^{-2} s^{-1}), V_2xFS (0.17 mol m^{-2} s^{-1}), V_3xFS (0.19 mol m^{-2} s^{-1}), V_4xFS (0.17 mol m^{-2} s^{-1}), V_5xFS (0.18 mol m^{-2} s^{-1}), and V_8xFS (0.17 mol m^{-2} s^{-1}), and they were found to be in the same group statistically. When plants are exposed to flooding stress, a decrease in stomatal conductivity occurs (Folzer et al. 2006). In addition to increased stomatal resistance in plants under flooding conditions, water deficiency occurs in cells due to limited water uptake (Parent et al. 2008). The decrease in O_2 level prevents root permeability and negatively affects hydraulic conductivity (Else et al. 2001). However, in some studies, there was no change in stomatal conductivity under stress conditions (Seymen et al. 2023). Although this depends on plant species exposed to flooding stress, it can be explained by the duration of stress.

Table 2

Effect of flood stress on GSW of melon cultivars (0.17 mol m^{-2} s^{-1})

Varieties (V)	Full Irrigation (I_{100})	Flooding Stress (FS)	Average
V-1	0.18[a]	0.13[e-h]	0.15[bcd]
V-2	0.15[cde]	0.17[ab]	0.16[bc]
V-3	0.19[a]	0,19[a]	0.19[a]
V-4	0.14[c-g]	0,17[ab]	0.16[bcd]
V-5	0.15[bcd]	0.18[a]	0.17[b]
V-6	0.14[c-g]	0.15[cde]	0.15[d]
V-7	0.14[d-h]	0.16[bc]	0.15[d]
V-8	0.13[gh]	0.17[ab]	0.15[cd]
V-9	0.14[c-g]	0.15[bcd]	0.15[d]
V-10	0.15[c-f]	0.15[cde]	0.15[cd]
V-11	0.13[fgh]	0.12[h]	0.12[e]
Average	0.15[b]	0.16 [a]	
LSD: 5%* and 1%** **V:**0.013** **FS:**0.005****VxFS:**0.018**			

*: Significant at 5%; **: Significant at 1%; and n.s: Not significant

The effects of flooding stress applied to different melon cultivars on the quantum efficiency (QPSII) of photosynthesis were found to be statistically significant (Table 3). In Table 3, the average was 0.66 under I_{100} conditions and it was 0.61 in cultivars exposed to flooding stress. The maximum mean QPSII was obtained from V-4 (0.64), V-5 (0.65), V-8 (0.65), V-10 (0.67), and V-11 (0.67) cultivars and were statistically included in the same group. Photosynthesis is an important process for plant development and biochemical events in the plant (Seymen et al. 2023).

The increase in leaf temperature under flooding stress conditions results closure of stomata, causing a decrease in the amount of photosynthesis (Barickman et al. 2019). Flooding stress limits influx of CO_2, leading to decreased photosynthetic efficiency and oxidative disrupt to photosynthesis II by ROS accumulation and ethylene accumulation (Rao & Li 2003; Bansal & Srivastava 2015). Castro-Duque et al. (2020) reported that flooding stress they applied in gooseberry negatively affected PSII and glycine betaine they applied made a significant contribution to PSII activity. Similar to literatures, flooding stress applied to melon led to a significant decrease in QPSII.

Table 3

Effect of flood stress on quantum productivity of photosynthesis (QPSII) of melon cultivars

Varieties (V)	Full Irrigation (I_{100})	Flooding Stress (FS)	Average
V-1	0.66^{a-e}	0.53^{i}	0.60^{d}
V-2	0.67^{a-e}	0.61^{fg}	0.64^{bc}
V-3	0.62^{efg}	0.56^{hi}	0.59^{d}
V-4	0.65^{b-f}	0.63^{d-g}	0.64^{abc}
V-5	0.70^{a}	0.60^{gh}	0.65^{abc}
V-6	0.66^{a-e}	0.61^{fg}	0.64^{bc}
V-7	0.65^{c-f}	0.59^{gh}	0.62^{cd}
V-8	0.67^{a-d}	0.63^{d-g}	0.65^{ab}
V-9	0.63^{d-g}	0.63^{d-g}	0.63^{bc}
V-10	0.68^{abc}	0.66^{a-e}	0.67^{a}
V-11	0.69^{ab}	0.65^{c-f}	0.67^{a}
Average	0.66^{a}	0.61^{b}	
LSD: 5%* and 1%** **V:**0.03** **FS:**0.01** **VxFS:**0,04*.			

The effects of flooding stress applied to different melon cultivars on the photochemical efficiency of PSII-Fv /Fm of photosystem II were found to be statistically significant (Table 4).

Table 4

Effect of flood stress on Fv/Fm of melon cultivars

Varieties (V)	Full Irrigation (I_{100})	Flooding Stress (FS)	Average
V-1	0.48	0.37	0.42^{e}
V-2	0.53	0.48	0.51^{abc}
V-3	0.49	0.50	0.49^{bcd}
V-4	0.49	0.45	0.47^{cde}
V-5	0.54	0.48	0.51^{abc}
V-6	0.58	0.55	0.56^{a}
V-7	0.52	0.46	0.49^{bcd}
V-8	0.49	0.41	0.45^{de}
V-9	0.51	0.51	0.51^{bc}
V-10	0.57	0.47	0.52^{abc}
V-11	0.59	0.46	0.53^{ab}
Average	0.52^{a}	$0,47^{b}$	
LSD: 5%* and 1%** **V:** 0.05** **FS:** 0.02** **VxFS:** $0,07^{n.s}$			

*: Significant at 5%; **: Significant at 1%; and n.s: Not significant

In Table 4, it was determined that while the average Fv/Fm value was 0.52 in different melon cultivars under full irrigation conditions, significant losses were observed in the cultivars under flooding stress and average was 0.47. The highest Fv/Fm values were obtained from V-2 (0.51), V-5 (0.51), V-6 (0.56), V-10 (0.52), and V-11 (0.53) melon cultivars. Damage to PSII can be detected by observing reduced maximum quantum yield (a measure of chlorophyll fluorescence proportional to the Fv/Fm ratio) in plants exposed to environmental stress (Nurrahma et al. 2021). In general, a decrease in Fv/Fm is an expression of a photo inhibition phenomenon (Björkman & Demmig 1987) which acts as a photo protective mechanism in the photosynthetic system (Krause & Weis 1991). Fv/Fm is an important indicator to examine tolerance to environmental factors of plants (Seymen at al. 2022; Seymen at al. 2023).

Significant reductions in Fv/Fm resulted from flooding stress conditions have been reported in cauliflower (Seymen et al. 2022), tomato (Kolton et al. 2020), pepper (Altaf et al. 2022), watermelon (Zheng et al. 2021), and rice (Nurrahma et al. 2021).

CONCLUSIONS

It was observed that effects of flooding stress applied on different melon cultivars on photosynthesis activities produced different findings. Although flooding stress did not have significant differences in leaf temperature, it led to significant reductions in quantum productivity of photosystem II. Sürmeli F1 (V-5), Kırkağaç local cultivar (V-10), Kyrgyzstan local cultivar (V-11) performed the highest photosynthetic activity and were found to be more tolerant cultivars to the flooding environments by comparison to other studied cultivars.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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