Plant Physiology and Biochemistry 106 (2016) 141–148

Contents lists available at ScienceDirect

Plant Physiology and Biochemistry

journal homepage: www.elsevier.com/locate/plaphy

Research article

# Effects of water stress and light intensity on chlorophyll fluorescence parameters and pigments of *Aloe vera* L.

Saeid Hazrati [a], Zeinolabedin Tahmasebi-Sarvestani [a, *], Seyed Ali Mohammad Modarres-Sanavy [a], Ali Mokhtassi-Bidgoli [a], Silvana Nicola [b]

[a] Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, Tehran, 14115-336, Iran
[b] Department of Agricultural, Forest and Food Sciences, VEGMAP, Univeristy of Turin, 10090, Italy

ARTICLE INFO

*Article history:*
Received 18 January 2016
Received in revised form
24 April 2016
Accepted 25 April 2016
Available online 26 April 2016

*Keywords:*
*A. vera*
Anthocyanin
Chl fluorescence
Light intensity
Water stress

ABSTRACT

*Aloe vera* L. is one of the most important medicinal plants in the world. In order to determine the effects of light intensity and water deficit stress on chlorophyll (Chl) fluorescence and pigments of *A. vera*, a split-plot in time experiment was laid out in a randomized complete block design with four replications in a research greenhouse. The factorial combination of three light intensities (50, 75 and 100% of sunlight) and four irrigation regimes (irrigation after depleting 20, 40, 60 and 80% of soil water content) were considered as main factors. Sampling time was considered as sub factor. The first, second and third samplings were performed 90, 180 and 270 days after imposing the treatments, respectively. The results demonstrated that the highest light intensity and the severe water stress decreased maximum fluorescence ($F_m$), variable fluorescence ($F_v$)/$F_m$, quantum yield of PSII photochemistry ($\Phi_{PSII}$), Chl and photochemical quenching (qP) but increased non-photochemical quenching (NPQ), minimum fluorescence ($F_0$) and Anthocyanin (Anth). Additionally, the highest $F_m$, $F_v/F_m$, $\Phi_{PSII}$ and qP and the lowest NPQ and $F_0$ were observed when 50% of sunlight was blocked and irrigation was done after 40% soil water depletion. Irradiance of full sunlight and water deficit stress let to the photoinhibition of photosynthesis, as indicated by a reduced quantum yield of PSII, $\Phi_{PSII}$, and qP, as well as higher NPQ. Thus, chlorophyll florescence measurements provide valuable physiological data. Close to half of total solar radiation and irrigation after depleting 40% of soil water content were selected as the most efficient treatments.



## 1. Introduction

Plants are exposed to different a biotic stresses such as high and low temperatures, water deficit, high light intensity, salinity, heavy metals and mechanical wounding under field conditions. In most cases, plants face several stresses at the same time and so they have developed sophisticated defense mechanisms to recognize and respond to a wide range of stresses (Mittler, 2006; Ibáñez et al., 2010). Thus, understanding their physiological processes and defense mechanisms of important for plant science research (Ibáñez et al., 2010; Wyka et al., 2012). Among environmental factors, light and moisture play major roles on plant growth and development (Jagtap et al., 1998). Light is known as the second most ecological factor affecting plant growth, production and survival and it is a major factor determining photosynthetic efficiency in plants, especially in the Crassulaceae family (Lüttge, 2004). In addition, water is another most important growth limiting factors in crop production and at the same time it is the most vital factors in physiological reactions.

Plants continuously adjust their growth and development to optimize photosyntheticactivity under fluctuating conditions. This developmental plasticity is achieved through the perception, transduction and integration of multiple environmental signals. For instance, energy lost in high light intensity is considerably more than in low light conditions (Valladares and Pearcy, 2002). It has been reported that high light intensities cause irreparable photoinhibitory damages to plant, particularly when water deficit stress

*Abbreviations:* $F_m$, maximal fluorescence level from dark adapted leaves; $F_m'$, maximal fluorescence level from leaves in light; $F_0$, minimal fluorescence level from dark-adapted leaves; $F_v/F_m$, maximal photochemical efficiency of the active center of PSII in the dark; $F_0'$, minimal fluorescence level of leaves in light; $F_s'$, Chl fluorescence yield during Actinic illumination irradiation; Chl, chlorophyll; Anth, anthocyanin; NPQ, non-photochemical quenching; qP, photochemical quenching; $\Phi_{PSII}$, quantum yield of PSII photochemistry.

* Corresponding author.
*E-mail address:* Tahmaseb@modares.ac.ir (Z. Tahmasebi-Sarvestani).

http://dx.doi.org/10.1016/j.plaphy.2016.04.046
0981-9428/

occurs at the same time (Hoch et al., 2001; Borkowska, 2002). High light intensities and water deficit stress negatively affect physiological processes (Thomas and Turner, 2001; Aranda et al., 2005; Zivcak et al., 2014). These factors affect photosynthesis and Chl fluorescence parameters directly or indirectly (Maxwell and Johnson, 2000). Although morphological and physiological responses to environmental stresses occur simultaneously, early detection of environmental stresses through physiological processes is possible (Naumann et al., 2007). In order to understand the physiological status of a certain plant and determine photosynthetic damage as affected by environmental stresses, Chl fluorescence assay is a rapid and, sensitive measure of photosynthetic competence in higher plants that can be used to detect the impact of such stresses on them (Baker and Rosenqvist, 2004; Calatayud et al., 2006). Under different environmental conditions, there are vast changes in Chl fluorescence. The light energy absorbed by Chl molecules can be directed in three ways: energizing photosynthesis, dissipation as heat or remission as fluorescence (Müller et al., 2001). It has been reported that, high light intensity causes a significant reduction in maximum fluorescence ($F_m$), variable fluorescence ($F_v$) and photochemical efficiency of photosystem II ($\Phi_{PSII}$) (Figueroa et al., 2003). Photosynthetic efficiency of photosystem II, both in the light ($\Delta F/F_m'$) and in a dark-adapted state ($F_v/F_m$) are the most widely used Chl fluorescence measuring parameter in plant research (Baker and Rosenqvist, 2004; Broetto et al., 2007). Under stressful conditions, there are several mechanisms to dissipate extra energy as heat or fluorescence (Naumann et al., 2007). Non-photochemical quenching (NPQ) is a protective mechanism that plants employ to dissipate excess light energy. Plants often absorb more light energy than they can process in photosynthesis. In this regard, it has been reported that high light intensity and water deficit stress increase NPQ while reduce $\Phi_{PSII}$ and qP (Miyake et al., 2005; Naumann et al., 2007; Ashraf and Harris, 2013). Similar results have been found by Herrera (2000) and Adams et al. (1987) who studied the effect of water deficit stress and high light intensity on mentioned parameters in crassulaceae plants. On the other hand, environmental stresses including high light intensity affect photosynthetic pigments and can inhibit photosynthesis (Ashraf and Harris, 2013). Light absorption is the first stage in photosynthesis, which is carried out by light absorbing pigments such as Chl and Anths (Liu et al., 2004). Light absorption efficiency depends on pigments concentration and its structure (Horton and Ruban, 2005; Porcar-Castell et al., 2014). Chl concentration varies according to environmental conditions. Some pigments such as Anths and carotenoids have been shown to act as a "sunscreen", protecting plant cells from high light damage by absorbing blue-green and ultraviolet light, thereby protecting the tissues from photo-inhibition, or high-light stress (Steyn et al., 2002; Hormaetxe et al., 2005). Anths and carotenoids concentration would increase to protect the chloroplasts under water deficit and high light intensity conditions (Gould et al., 2000; Horton and Ruban, 2005; Hatier and Gould, 2008). Increase in Anth concentration under unfavorable environmental conditions has been reported in other studies (Chalker-scott, 1999; Hughes et al., 2005; Albert et al., 2009). Increase in Anth and rhodoxanthin concentration due to high light intensity has been previously reported by Lüttge (2000) in *Aloe vera*. In this plant, leaves turn red or brown under environmental stress conditions (Cousins and Witkowski, 2012). Chl fluorescence responses to environmental stresses faster than Chl content, therefore study on fluorescence variations would help us to understand physiological status of the plants. There are fewer information on Chl fluorescence and pigments changes as affected by environmental stress in *A. vera*. Since this plant is a succulent species with crassulacean acid metabolism (CAM) photosynthetic $CO_2$ fixation pathway, it usually grows in warm and dry regions where light intensity is extremely high. The plant at maturity stages requires more light than early stages of growth. Considering the photosynthetic $CO_2$ fixation pathway in *A. vera*, study on the effect of light intensities and water deficit stress would help us to understand physiological changes in this plant. While there are several studies focusing on light intensity or water deficit stress as separate factors (Paez et al., 2000; Rodríguez-García et al., 2007; Lucini et al., 2013); a comprehensive study to determine the outcomes and impacts of this two factor interactions has not been carried out so far. Hence, the current study was aimed to evaluate the effects of different light intensities and water deficit stress levels on Chl fluorescence parameters and pigments to find out their relationships during plant growth stages.

## 2. Material and methods

### 2.1. Experimental design, treatments and growth conditions

A split-plot in time experiment was laid out in a randomized complete block design with four replications in a research greenhouse situated in Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran during 2013 and 2014 growing seasons. The factorial combination of three light intensities (50, 75 and 100% of sunlight) and four irrigation regimes (irrigation after depleting 20, 40, 60 and 80% of soil water content) were considered as main factors. Sampling time was considered as sub factor. The first, second and third samplings were performed on 22nd September 2013, 20th January and 21st March 2014, respectively, at 90, 180 and 270 days after imposing the treatments. The 18–20 cm pups (small plants growing from the sides of the mother plant) were planted in plastic pots and placed in greenhouse for two months, irrigated equally. Thereafter, plants were transplanted into new pots filled with 18 kg homogeneous soil and then irrigation regimes were imposed for the next 9 months. At the same time, plants were subjected to different light intensities by placing them under a nylon mesh tent to reduce the sunlight intensity by 50 and 75%. The light intensity under the tents was measured using portable solarimeter (118 HAENNI) at noon (Fig. 1). The greenhouse temperature was adjusted on 28 and 22 °C in days and nights, respectively.

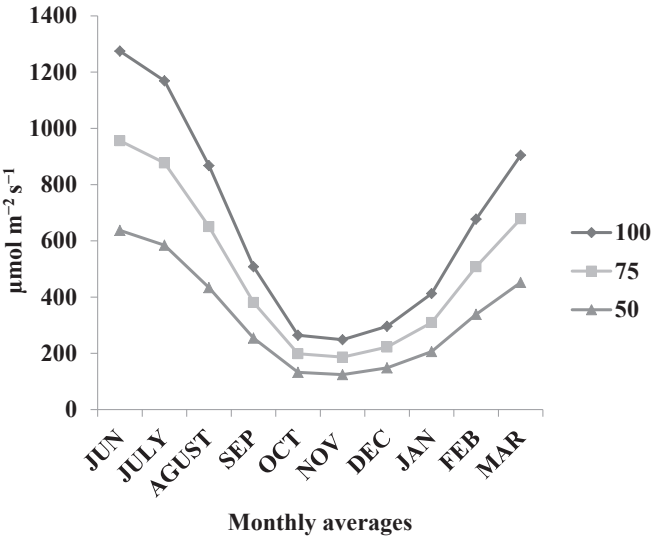


**Fig. 1.** Monthly averages of light intensity during growth of *A. vera*.