Available online at www.sciencedirect.com
ScienceDirect
Environmental and Experimental Botany 58 (2006) 1–8
Environmental and Experimental Botany
www.elsevier.com/locate/envexpbot

Some physiological and growth responses of watermelon [C*itrullus lanatus* (Thunb.) Matsum. and Nakai] grafted onto *Lagenaria siceraria* to flooding

Halit Yetisir [a,*], Mehmet E. Çaliskan [b], Soner Soylu [c], Musa Sakar [a]

[a] *Department of Horticulture, Faculty of Agriculture, University of Mustafa Kemal, 31120 Hatay, Turkey*
[b] *Department of Field Crops, Faculty of Agriculture, University of Mustafa Kemal, 31120 Hatay, Turkey*
[c] *Department of Plant Protection, Faculty of Agriculture, University of Mustafa Kemal, 31120 Hatay, Turkey*

Received 3 January 2005; accepted 15 June 2005

Abstract

In this study, the effect of flooding on plant growth and photosynthetic activity of grafted watermelon were investigated. The watermelon [C*itrullus lanatus* (Thunb.) Matsum and Nakai] cv. 'Crimson Tide' was grafted onto *Lagenaria siceraria* SKP (Landrace). Grafted and ungrafted watermelon plants were flooded at the soil surface for 20 days. For every 5 days, three plants were sampled to determine plant fresh and dry weight, leaf number and main stem length. Leaf colour, single leaf CO_2 exchange rate (CER), stomatal conductance (SC) and transpiration rate (Ts) were determined at 3 days interval. Flooding caused chlorosis on both grafted and ungrafted plants but such effect was more pronounced on ungrafted watermelon plants. CER, SC and Ts began to decrease from the 4th day of the flooding in both grafted and ungrafted plants as compared with non-flooded controls. However, grafted plants showed higher tolerance to flooding and had two-folds more CER, SC and Ts. Plant growth rate was also significantly lower in flooded plants than when compared to unflooded controls. Ungrafted plants had lower dry weight than grafted plants under flooding conditions. At the end of the experiment, decrease in fresh weight of plants was about 180% in ungrafted and 50% in grafted watermelons. Dry weight also decreased about 230% in ungrafted and 80% in grafted watermelons. Similar results were found in leaf number and main stem length. Adventitious roots and aerenchyma formation were observed in grafted watermelon but not in ungrafted watermelon under flooding. Adventitious root formation began from 3rd or 4th day of flooding and adventitious roots grew towards the soil surface. Flooding tolerance of watermelon could be improved by grafting onto *L. siceraria*.

Keywords: Flooding; Grafting; *Lagenaria siceraria*; Photosynthetic rate; Watermelon

1. Introduction

Flooding and submergence are major abiotic stresses and are serious problems for the growth and yield of flood-sensitive crops. Flooding conditions cause oxygen starvation, which arises from the slow diffusion of gases in water and oxygen consumption by microorganisms and plant roots. Flooded soil quickly becomes devoid of oxygen at depths below a few millimetres. In the floodwater itself, a broad unstirred boundary layer occurs around respiring tissue. This formation can lead to tissue oxygen deficiency within a few hours. Respiring tissues such as root and rhizomes may die because of the oxygen deficiency and a rapid drop in energy-rich adenylates causing a dramatic decrease in ion absorption and transport (Huang et al., 2003; Vartapetian et al., 2003). Water potential of flood-intolerant plants can decrease (Trought and Drew, 1980; Savé and Serrano, 1986; Smith and Ager, 1988; Liao and Lin, 1995) and leaf stomatal conductance can decrease, resulting in poor gas exchange rate (Andrews and Lorimer, 1987).

Some plants have evolved a wide range of characteristic responses that appear to help withstand the effect of the stress. Several anatomical responses facilitate internal transport of oxygen by diffusion or sometimes by mass flow.

* Corresponding author. Tel.: +90 326 2455845; fax: +90 326 2455832.
E-mail addresses: yetisir1@yahoo.com (H. Yetisir), mehmet@mku.edu.tr (M.E. Çaliskan), soylu@mku.edu.tr (S. Soylu).

0098-8472/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.envexpbot.2005.06.010

This allows underground organs to avoid developing anaerobic interiors. Of particular importance is the development of aerenchyma, which can be described as gas-filled channels that can interconnect throughout much of the plant. This creates a low resistance network for the transport of gases from well-aerated aerial parts to organs engulfed by anaerobic surroundings (Aschi-Smiti et al., 2003; Colmer, 2003). Aerenchyma can be also developed in newly formed adventitious roots that emerge at the base of the shoot by many non-wetland herbaceous species in response to water logging or low oxygen concentration. Thus, these specialized roots are adapted anatomically to oxygen deficient media. It is widely assumed that aerenchyma cells functionally replaced the original root system, which is inhibited or killed by lack of oxygen (Jackson, 1955; Yu et al., 1969).

Problems caused by flooding may be solved by growing flood-tolerant crops or grafting intolerant plants onto tolerant ones. This technique is widely used in fruit trees. Grafting has been performed in fruit-bearing vegetables against the soil-borne disease and some other negative soil conditions since 1927 (Lee, 1994). Liao and Lin (1996) reported that bitter melon grafted onto *Luffa* had higher rubisco and photosynthetic activities than ungrafted bitter melon under flooding conditions.

Watermelons are grafted in order to be protected from *Fusarium* wilt, to increase low soil temperature tolerance and to increase yield by enhancing water and plant nutrients uptake (Masuda et al., 1981; Jang, 1992; Heo, 1991; Oda, 1995). For these purposes, watermelons are grafted onto *Cucurbita moschata*, *C. maxima*, *Benincasa hispida* and *Lagenaria siceraria*. *L. siceraria* is a widely used species as rootstock for watermelon (Lee, 1994). Several studies on the effect of grafting on yield, quality and tolerance to some abiotic stresses such as low soil temperature and salinity have been conducted in watermelon (Balaz, 1982; Lee, 1994; Oda, 1995; Chouka and Jebari, 1999; Yetisir et al., 2003; Yetisir and Sari, 2003). To the best of our knowledge, the effect of flooding on grafted watermelon onto *L. siceraria* was not reported in previous studies.

We observed that *L. siceraria* has a more vigorous root system and aerial parts than watermelon, and formed more adventitious roots. These observations led us to hypothesize that grafted watermelon plants would express greater biomass and photosynthetic activity than ungrafted watermelon under flooded conditions. To test this hypothesis, photosynthetic activity, growth rate and plant leaf colour change of grafted watermelon onto *L. siceraria* were investigated for different duration of flooding and compared with those of ungrafted watermelon of a similar period of flooding.

2. Material and methods

2.1. Plant material and culture conditions

The watermelon [C*itrullus lanatus* (Thunb.) Matsum. and Nakai] cv. 'Crimson Tide' was grafted onto the landrace of *L. siceraria*, SKP. Seeds of 'Crimson Tide' were sown on March 19, 2004 and seeds of rootstock (SKP) were sown on March 22, 2004 in peat and perlite 2:1 (v/v) mixture. The seeds were sown first in multipots, when seedlings reached the first true leaf stage (diameter of the leaf was about 2 cm) the grafting was performed. The hole insertion grafting technique was used and plants were grafted following the procedure described by Lee (1994) and Lee and Oda (2003). Seedlings were grown in an unheated greenhouse under plastic tunnel. After 20 days of grafting, surviving grafted plants and ungrafted plants were transplanted in 2 L pots filled with peat and perlite mixture. Growth medium was amended with 500 g/m^3 of N, P_2O_5 and K_2O. Grafted seedlings grown to the three to four true leaf stages were used for experiments. For flooding treatment, the potted grafted and ungrafted plants were submerged to the level of the soil surface for different periods of time (5, 10, 15 and 20 days) in three steel containers (2.5 m length, 1 m width and 0.3 m depth). For flooding, tap-water with EC = 0.5 dS/m and pH 7.00–7.40 was used. At the same time, grafted and ungrafted plants without flooding were also grown. Analysis and measurements of controls were carried out at the same time as with the treatments of various flooded plants. The experimental design was a completely randomized block design and each treatment was replicated three times with 15 plants in each replicate.

2.2. Measurement of leaf CO_2 exchange rate, stomatal conductance and transpiration rate

CO_2 exchange rate (CER), stomatal conductance (SC) and transpiration rate (Ts) were collected with a portable photosynthesis analyzer (Model LCA-4, ADC Bioscientific Ltd., Hoddesdon, UK). Measurements were taken from the most recent, fully expanded terminal leaf of each plant. The measurements were conducted under full sunlight between the hours of 13:00 and 14:00 under clear sky conditions. Measurements was started on the first day of flooding then continued by 3 days interval for 15 days.

2.3. Biomass measurement

For biomass measurements, three plants per replication were sampled at 0, 5, 10, 15 and 20 days after flooding. Total fresh weight, leaf number and main stem length were determined for each plant and means were calculated for each replicate. The plant material was dried at 68 °C for 48 h and then weighted for dry weight.

2.4. Leaf colour measurement

Plant leaf colour was measured as reflected in the CIELAB ($L^*a^*b^*$) colour space using a Minolta model CR-300 Colorimeter (Minolta, Osaka). Two readings (from young and old leaves) were performed from each plant by 2 days interval and continued for 14 days. L^* represents lightness ranging