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A REVIEW OF THE DEFICIT IRRIGATION ON THE FRUIT TREES

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Abstract
Irrigation is a vital management practice in fruit production regions of the world, particularly in arid and semi-arid climates. Vegetative and fruit growth are differentially sensitive to water deficit during the season depending on the stage of fruit growth. Deficit irrigation improve fruit composition and, in the short-term, increased tree water use efficiency because the water stress applied allow for an optimization of the balance between vegetative and productive growth. Insufficient water supply in the long-term may result in reduced tree growth, yield and fruit quality due to water stress. Deficit irrigation can be used in management strategy to reduce non-productive water consumption. The focus of the review is to present the results of studies and articles about to deficit irrigation on the fruit trees. The use water in regions with water deficit requires innovative and sustainable research, and an appropriate transfer of technologies. First, the paper proposes some concepts relative to water deficit.

Keywords: drought, soil water content, water stress

1. INTRODUCTION

Water deficit is the most common environmental stress factor limiting plant productivity. The ability of plants to tolerate water deficit is determined by multiple biochemical pathways that facilitate retention and/or the acquisition of water. Drought is one of the major constraints on agricultural productivity worldwide and it is likely to further increase. Drought occurs as a result of low rainfall, high temperatures or wind and it is not a uniform phenomenon. From the agronomic point of view, the water stress is installed when the needs of the plants for the water exceed the existing reserves in the environment.

For the possible future global warming, when water use becomes increasingly restrictive, deficit irrigation is a reasonable solution for water conservation. The current paper presents a review of the research on deficit irrigation of the fruit trees.

2. THE CONCEPT OF DEFICIT IRRIGATION

Deficit irrigation (DI) strategy was proposed many years ago to improve water productivity and reduce water application. DI is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop, resulting in plant drought stress, production loss, but maximizing irrigation water productivity (English, 1990); DI is actually applied to the whole crop season in both sensitive and non-sensitive periods, but emphasis is put on the first. Other authors have also reported that in arid regions, irrigation should increase water use efficiency and decrease the impact on the environment, preserving soil and water quality (Dichio et al., 2011). In the short term, DI leads to water saving without yield loss (Naor, 2006, Fereres and Soriado, 2007), while in

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the long-term fruit yield can be reduced due to the cumulative effects on trees (Intrigliolo et al., 2005). Among the scientists dealing detailed aspects of water stress one can mention the contribution of Chalmers et al. (1981), Mitchel and Chalmers (1982), Caruso et al. (2001), Goldhamer et al. (2002), Brylaet al. (2005), Glenn et al. (2006), Abrisqueta et al. (2008), Vallverdu et al. (2012), Paltineanu et al. (2013, 2015).

Sustained deficit irrigation is an irrigation strategy based on the distribution of a reduced water volume, controlled by a water stress indicator or as a percentage of the full water requirements for a crop throughout the whole irrigation season, so that the water deficit is intended to be uniform over the whole crop cycle to avoid the occurrence of severe water stress at any particular moment that might have unfortunate results (Sofo et al., 2012).

One of the most promising techniques is the use of deficit irrigation (DI). The research has revealed the potential of this strategy as a way to reduce water consumption in fruit trees with a reduced impact on yield and fruit quality. In addition, in order to contribute to water saving, fruit culture should be directed towards the use of plant materials that are less water-demanding or able to withstand deficit irrigation.

3. WATER RELATIONS, VEGETATIVE AND FRUIT GROWTH

Under the conditions of Constanta, Romania, to peach, soil water content (SWC) ranged between 60 and 76% of the plant available water capacity (AWC) in T1-fully irrigated according to the irrigation needs calculated with the help of ETc (PM-ETo multiplied by Kc according to Allen et al. (1998) as previously described for the region by Paltineanu et al., (2007) these values justified the fact that T1 was practically non-stressed, between 40 and 62% in T2- a deficit irrigation treatment, with half the amount of water in T1 and between 30 and 45% in T3- control, a non-irrigated treatment (Paltineanu et al., 2013).

Studies on soil and plant water status in response to water deficits have pointed to a reduction in the soil water content as the first signal that can be used as a stress indicator (Ruiz-Sanchez M.C., 2010). For irrigation management, different devices have been used to monitor the soil water content tensiometers (Li et al., 1989), granular matrix sensors (Intrigliolo and Castel, 2006), capacitance probes (Abrisqueta et al., 2011) or Watermark resistance blocks (Paltineanu et al, 2013, Septar et al., 2019).

For the application of watering with maximum efficiency different indicators of the degree of tolerance/resistance to the water stress of the fruit trees are needed. The crop water stress index (CWSI) is an indicator of the rate of relative transpiration of a plant, which depends on the difference between the temperature of the leaf and the air, and the pressure deficit of the water vapor in the atmosphere. As the water level in the plant drops, the stomata closes and the intensity of perspiration decreases, while the temperature of the foliar apparatus exposed to direct solar radiation increases (Testi et al., 2008, Paltineanu et al, 2013, Osroosh et al. 2016). When a plant is well supplied with water, it transpires with great intensity, the level of leaf temperature being lower than the average temperature, and the greater the saturation deficit of water vapor in the atmosphere (1-12°C), in this case the CWSI value, approaches 0. When the intensity of perspiration is reduced, the temperature of the leaves exposed to direct solar radiation increases and can exceed the air temperature by 4-6°C. When the plant reduces its sweating, CWSI tends to value 1 (Osroosh et al. 2016). Sweating is amplified by the water vapor saturation deficit of the atmosphere. The use CWSI is preferred in agriculture, being one of the best indicators for irrigation planning and management. In sunny leaves case, the CWSI values of 0.18-0.20 are appropriate for irrigation application in the case medium-textured and relatively homogeneous soils in irrigation scheduling for peach orchards

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grown under conditions similar to Constanta, Romania, and neighboring countries (Paltineanu et al, 2013).

Most of the studies that we have reviewed show that the foremost benefit of using DI is to reduce the amount of irrigation and increase WUE, but crop yield can be increased, maintained, or decreased; this has been demonstrated in many crop species such pear–jujube tree (Cui et al. 2009), almond (Egea et al. 2011), apple (Van Hooijdonk et al. 2004), and peach (Gelly et al. 2004). Under the conditions of Constanta, Romania the deficit irrigation treatment showed higher WUE values ranging from 50 to 212 kg mm-1of irrigation water, vs. the non-stressed treatment with 43-144 kgmm^{-1} of irrigation water (Paltineanu et al., 2013).

The vegetative growth of fruit trees is recognized as being the most sensitive process to DI. Reductions in shoot elongation and trunk cross sectional area in response to water deficits lead to reductions in tree size and smaller canopies (Intrigliolo and Castel, 2006; Marsal et al., 2008; Pérez-Pastor et al., 2009). Sensors like linear variable displacement transducers (LVDTs) are able to measure daily trunk diameter fluctuations (TDF) with great precision, generating sensitive parameters which strongly correlate with established plant water status parameters (Fernandez and Cuevas, 2010, Ortuño et al., 2010). The most common and useful TDF parameters for the irrigation scheduling of fruit trees are maximum daily trunk shrinkage (MDS) and trunk growth rate (TGR) (Ortuño et al., 2010, Moriana et al., 2013).

The management of deficit irrigation with a continuous measurement of the water status would allow obtaining an accurate estimation of the water needs. However, although different types of sensors are available, the threshold and daily management of these data are not clearly defined. TDF are a good example of these type of data. TGR is considered an early indicator in trees. However, the daily TGR values are very changeable, and only cumulative values of TGR show a clear trend. The number of irrigation works using this indicator is scarce (Corell et al., 2017).

Stone hardening period is the phenological stage when water stress is recommended in deficit irrigation in trees. Fruit growth is a very important process which could affect the final profit of the yield. DI scheduling based on water status measurements could improve water management, but accurate threshold values are needed. Previous works in low fruit load conditions suggested −1.8 MPa of midday stem water potential as "first step" of water stress level where no variations of fruit growth have been detected (Giron et al., 2015). Several studies have addressed the use of deficit irrigation, in peach. Chalmers et al., (1981) have applied the method to peach during the phase of final swell and observed a significant production and fruit growth increase, if irrigation restrictions were applied while excessive vegetative vigor could be suppressed to favor fruit growth.

Fruit water accumulation is highly sensitive to the level of water deficit during all fruit developmental stages, whereas dry matter accumulation is relatively insensitive (Girona et al., 2004). In mid-season maturing cultivars, the best strategy maybe a combined deficit irrigation strategy (Girona et al.2003), with water restrictions applied during stage II of fruit growth in order to reduce shoot growth there by decreasing the vegetative growth competition and to improve fruit composition, and then applied again during post-harvest, with the main goal to save water. When moderate water deficits were applied during early stages of fruit growth, fruit growth was not reduced compared with fully irrigated trees; moreover, fruit growth was even stimulated due to an accelerated rate of growth when irrigation was increased to 100% ETc during the subsequent stages, as it has been found in apricot (Ruiz Sánchez et al., 2000), peach (Girona et al., 2003), citrus (González-Altozano and Castel, 2000), pear (Caspari et al., 1994), apple (Ebel et al., 1995).

Fruit mass and chemical composition depends not only on irrigation regime, but also on soil properties, fertilization amount, and other environmental characteristics, and of course, on the

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cultivar studied.
Under the conditions of Constanta, Romania, fruit mass for Southland cultivar ranged from 172 to 182g in fully irrigation, 153 to 176 in deficit irrigation treatment and 118 to 160 g in control, nonirrigated treatment. The analysis of variance revealed that the total dry matter content was significantly different in their irrigated treatments, with values of 11.5% in fully irrigation and 12% in deficit irrigation treatment, vs. the control which showed higher values (13.2%) (Paltineanu et al., 2013).
In Turkey under various water deficit conditions, fruit mass for Redhaven cultivar varied from 203 to 253 g and soluble dry matter content ranged between 10.8 and 14.5% (Gunduz et al., 2011). Fruit tree productivity is the result of several interactive components (tree size and shape, flowering and fruit set and fruit growth) that can be greatly influenced by the tree water status (Naor, 2004).
For peach, considering the available information on the use of DI, production is not significantly affected as long as applied in an adequate phase and bearing in mind, the variety relative precocity. Other advantages can be pointed out such as an easier management of the crop (if the vegetative vigor is restrained) and an increased efficiency in the use of water resources. Precaution is advised concerning long-term cumulative effects in production, as sometimes a negative influence has been observed (Fernandes et al., 2019).

4. CONCLUSIONS

- Water deficit is an inevitable consequence of life for terrestrial plants. A variety of mechanisms have evolved to control plant water status, regulate water loss, maintain turgor pressure, and reduce water transport out of plant systems. Many water-saving practices have been adapted to tackle the critical issue of water shortage worldwide.
- In opposition to possible global warming, when water becomes more and more expensive and less accessible, sustained (50% ETc) irrigation strategy under sustained (continuous) water stress becomes a viable option, necessary for water saving;
- The main periods of vegetative and fruit growth must be clearly differentiated for the successful application of deficit irrigation in fruit trees.
- In order to contribute to water saving, fruit culture should be directed towards the use of plant materials that are less water-demanding or able to withstand deficit irrigation.
- The variation in response of fruit trees to deficit irrigation is probably due to the interaction of the water restriction with other external (soil and climatic factors) and internal (tree nutritional status crop level and training system) factors that determine the degree of actual water stress suffered by the tree.
- Deficit irrigation improve fruit composition and, in the short-term, increased tree water use efficiency because the water stress applied allow for an optimization of the balance between vegetative and productive growth.

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