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Research article

Regulation and physiological role of silicon in alleviating drought stress of mango

Mohamed Naser Helaly [a], Hanan El-Hoseiny [b], Nabil Ibrahim El-Sheery [c], Anshu Rastogi [d, e], Hazem M. Kalaji [f, g, *]

[a] Agricultural Botany Department, Faculty of Agriculture, Mansoura University, El-Mansoura, Egypt
[b] Horticultural Research Institute, Agricultural Research Center, Giza, Egypt
[c] Agricultural Botany Department, Faculty of Agriculture, Tanta University, Tanta, Egypt
[d] Department of Meteorology, Poznan University of Life Sciences, Piątkowska 94, 60-649 Poznan, Poland
[e] Department of Plant Physiology, Slovak University of Agriculture, A. Hlinku 2, 94976 Nitra, Slovak Republic
[f] Department of Plant Physiology, Faculty of Agriculture and Biology, Warsaw University of Life Science – SGGW, Nowoursynowska 159, 02-776 Warsaw, Poland
[g] SI TECHNOLOGY, Gorczewska 226C/26, 01-460 Warsaw, Poland

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ABSTRACT

Improvement of drought stress of mango plants requires intensive research that focuses on physiological processes. In three successive seasons (2014, 2015and 2016) field experiments with four different strains of mango were subjected to two water regimes. The growth and physiological parameters of possible relevance for drought stress tolerances in mango were investigated. Yield and its components were also evaluated. The data showed that all growth and physiological parameters were increased under K_2SiO_3 (Si) supplement and were followed by the interaction treatment (Si treatment and its combination with drought stress) compared to that of the controlled condition. Drought stress decreased the concentration of auxins (IAA), gibberellins (GA) and cytokinins (CK) in the three mango cultivars leaves, whereas, it increased the concentration of abscisic acid (ABA). On the contrary, IAA, GA, and CK (promoters) endogenous levels were improved by supplementing Si, in contrary ABA was decreased. Drought stress increased the activity of peroxidase (POX), catalase (CAT), and superoxide dismutase (SOD) in the leaves of all mango cultivars grown during three experimental seasons. However, Si supplementation reduced the levels of all these antioxidative enzymes, especially the concentration of SOD when compared to that of control leaves. Fruit quality was improved in three successive seasons when Si was applied. Our results clearly show that the increment in drought tolerance was associated with an increase in antioxidative enzyme activity, allowing mango plants to cope better with drought stress. Si possesses an efficient system for scavenging reactive oxygen species, which protects the plant against destructive oxidative reactions, thereby improving the ability of the mango trees to withstand environmental stress in arid regions.

1. Introduction

Mango (*Mangifera indica* L.) a member of family Anacardiaceae is considered to be the king of fruits and represents one of the most important fruit crops grown in tropical and subtropical climates. It can also be successfully cultivated in all irrigated semiarid regions around the world. Egypt is one of the semi-arid countries successfully cultivating and producing lots of mango cultivars. The genus *Mangifera* contains several species that bear edible fruits. Most of the fruit trees are commonly known as mangos and belong to the species *indica*. The other edible *Mangifera* species generally have a lower quality fruit and are commonly referred to as wild mangos (Jiskani et al., 2007). The growth of mango is not continuous but occurs intermittently, with short-lasting flushes of shoots from the apical or lateral buds. Vegetative growth occurs on individual stems up to four times a year, depending upon the cultivars

* Corresponding author. Department of Plant Physiology, Faculty of Agriculture and Biology, Warsaw University of Life Science – SGGW, Nowoursynowska 159, 02-776 Warsaw, Poland.
E-mail address: hazem@kalaji.pl (H.M. Kalaji).

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and growth conditions (Santos et al., 2014). Under conditions of arid and semi-arid regions, like Egypt, the limited supply of suitable water is considered a major problem and restricts agriculture development in desert areas. In addition, tree roots are frequently exposed to a high water table, questionable irrigation practices, or saline water. This is attributable to wide tree-spacing malformation, alternate bearing, environmental factors, and fruit drop (Cifre et al., 2005).

Environmental factors, such as soil moisture content, can have a profound effect on plant metabolism and development. Repeated water deficits can reduce the sensitivity of stomata to a low potential for water. This deficit is typically characterized by decreases in water content, turgor, and total water potential, partial or complete closure of the stomata, and reduction in the rate of cell enlargement and growth (Cotrim et al., 2011). Water deficit or stress is the result of the interaction between factors in the rhizosphere, plant and the atmosphere in relation to the amount of moisture available to plants.

The deficit in irrigated water is a serious problem facing mango cultivars in all semiarid countries. Much effort has been undertaken worldwide to improve efficiency when using irrigation water for various fruit crop species (Cifre et al., 2005). Water stress has a major effect on certain phases of the plant cycle than on others (Tongetti et al., 2005). Exposure to moisture stress at the seedling stage confers some degree of a “hardening” against current and later drought periods (Santos et al., 2015).

On the other hand, it was found that the flowering, harvesting, higher fruit retention, and the yield and quality of mango all largely depend on irrigation, which is applied at the appropriate time in an adequate amount (Li et al., 2000). It is therefore vital to understand whether a plant simply responds, or adapts, to the effects of water stress.

Modern micro irrigation methods, such as sprinkler, drip, subsurface, pitcher, and bubbler, have a great water saving potential. According to Yildirim and Korukcu (2000), drip irrigation generally achieves a better crop yield and balanced soil moisture in the active root zone with a minimum loss of water. On an average, drip irrigation saves about 70%–80% water as compared to conventional flooding or furrow irrigation methods (Ishfaq, 2002). Some of the progressive growers have changed irrigation strategies and now are applying modern micro irrigation methods.

Many attempts have been established to improve drought stress by using non-traditional methods. A number of mechanisms can contribute to the drought in different plant species. This includes morphological characters, such as the deep rooting or metabolic regulating mechanisms like osmotic adjustment. The regulation of deficit irrigation has been the goal of several crops in the stages of plant development, in where growth and quality have a low sensibility to water deficit, such as in mango (Cotrim et al., 2011; Santos et al., 2013, 2014).

Qin and Tian (2009) suggested that silicon (Si) is beneficial in protecting plants from all stresses by activating a natural defense reaction and producing phenolic compounds that act as antioxidants. Si is a major constituent of many plants, but is not generally classified as essential. However, it has been regarded as an essential in a number of species, such as Poaceae and Cyperaceae. Si is beneficial in enhancing the tolerance of mango trees against biotic and abiotic stress, water and nutrient uptake, photosynthesis, and water transport (Santos et al., 2014). Previous studies show that Si had an unexpected promotive effect on the growth, yield, and fruit quality of different fruit crops (Cotrim et al., 2011; Neumann & Zur-Neiden, 2011). These studies show a water and energy saving, an improvement in fruit quality, and an increase in yield. Qin and Tian (2009) reported that even under optimal conditions many metabolism processes produce reactive oxygen species (ROS). The production of toxic oxygen derivations is increased as a result of all types of abiotic or biotic stress. Plants possess efficient systems for scavenging ROS that protect them from destructive oxidative reactions. Si has been reported to minimize the stress in different plant species (Jayawardana et al., 2014) and may be involved in the metabolic or physiological activity in plants exposed to stress. However, little research has been done on the direct effects of stress factors on the physiological processes affecting dry matter production. The investigation of mechanisms of drought tolerance in mango therefore requires research focused on physiological processes such as photosynthesis, assimilation, degradation and translocation (Bloch and Hoffimann, 2005).

The present investigation aimed to evaluate the differences in drought tolerance in the presence or absence of Si between four cultivars of mango grown in Egypt. The efficiency of irrigation water and Si treatments used on certain physiological characters were also evaluated.

2. Materials and methods

The present investigation was carried out in an orchard located at Wadi El-Molok El-Sharkia governorate, Egypt for three successive seasons from 2014 to 2016.

Four, 20 year old, mango (*Mangifera indica* L.) cultivars (cv), planted 7 m apart and subjected to regular orchard management were selected and evaluated under two water regimes for the presence or absence of potassium silicate (K_2SiO_3 25% Si and 10% K_2O_3) to. These cv(s) were named Ewaise (1), Hindy (2), Misk Ewaise (3), and Fagri Kalan (4). The surface and subsurface soil samples were analyzed according to Klute and Dirksen (1986) and are presented in Table 1. A drip irrigation system was used in the orchard. The system was set up at six and three drippers per hole for control and moisture stress conditions, respectively. The water potential (Ψ_s) was −0.18 and −0.77 bars in the control and water stressed condition, respectively. Si was added as a potassium silicate (K_2SiO_3 25% Si and 10%K_2O_3) to the regular irrigation pumped system once every two weeks at the rate of 1.5 mM Si, the pH after Si addition was adjusted to 6.9 with H_2SO_4 supplementation. Each tree received 20 m^3 and 10 m^3 irrigation water during the whole season, respectively for the control and stress treatments, i.e. 30 gm and 15 gm Si was supplied to tree through irrigation. A randomized complete block design with three replicates was used.

3. Sampling

To evaluate the treatments tested the following parameters were recorded.

1. Growth

1.1. Percentages of vegetative growth at spring cycle (V.G%) using the following formula:

$$\mathbf{V}.\mathbf{G}\% = \frac{Number\ of\ emerged\ flushes\ per\ vegitative\ \ cycle}{Total\ number\ oftagged\ shoot} \times 100$$

1.2. Leaf area (cm^2 of the 4th leaf from the plant tip). This was recorded for 4 different branch directions using the formula of Nii et al. (1995).

$$Y = -0.146 + 0.706 \times (r^2 = 0.995)$$