Physiological responses of two tomato (Lycopersicon esculentum M.) cultivars to Azomite fertilizer under drought stress

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Abstract

This study was conducted in order to investigate the effect of drought stress and Azomite fertilizer on some physiological traits of two tomato (Lycopersicon esculentum M.) cultivars (izmir and Izabella). A randomized complete design with factorial arrangement with three replications was used. Treatments consisted of three levels of irrigation including FC (control), 2/3 FC (mild drought stress), and 1/3 FC (severe drought stress) along with four levels of Azomite (0, 25, 50 and 100g/pot). Results showed that drought stress reduced stem length, plant dry and fresh biomass, relative growth rate (RGR), net assimilation rate (NAR), relative water content (RWC), total chlorophyll, carotenoid, nitrogen, phosphorus and potassium in leaves. Azomite fertilizer increased the stem length, plant dry and fresh biomass, RGR, NAR, RWC, total chlorophyll, carotenoid, nitrogen, phosphorus, and potassium in leaves in comparison with control plants in both cultivars. Interaction effect of drought stress and Azomite had a significant effect on increasing plant fresh biomass, RGR, NAR, RWC, total chlorophyll, carotenoid, nitrogen, phosphorus, and potassium in leaves in comparison with control plants in both cultivars. Interaction effect of drought stress and cultivar showed significant effect on increasing plant fresh biomass, RGR, RWC, total chlorophyll, and phosphorus. Moreover, the results indicated that the interaction effect of Azomite and cultivar had a significant effect on plant fresh biomass, RGR, RWC, and phosphorus in leaves. In general, Azomite was effective on drought stress tolerance of tomato plant.

Key words: Lycopersicon esculentum; azomite; drought stress; chlorophyll; RWC

Abbreviations

FC: field capacity; NAR: net assimilation rate; RGR: relative growth rate; RWC: relative water content


Introduction

Studies show that water shortage delays growth and development in plant, reduces leaf size, and causes anatomical changes due to alteration in cell size, senescence, and ultimately...
death in many plant species (Jaleel et al., 2008). Reduction in water absorption in drought stress conditions decreases intracellular water and turgidity pressure, which subsequently limits cell division and development through mitosis and reduces growth (Osakabe et al., 2004). One of the most accurate ways to study plant reactions to environmental conditions is through evaluation of physiological growth indicators (Karimi and Siddique, 1991). Relative Growth Rate (RGR) is a good indicator to present plants with improvement capability against detrimental effects of drought stress (Xu et al., 2009). Studies show that drought stress reduces relative growth rate in tomato (Sanchez-rodriguez et al., 2010). Moreover, drought stress reduces nutrient absorption and subsequently decreases cell growth and development, leaf development, and biomaterials’ absorption, composition, and transfer in plants. Drought stress also reduces root capacity to absorb water and nutrients from soil due to reducing nutrient absorption in plants (Osakabe et al., 2014).

Nitrogen is an important element in providing carbon skeleton and producing metabolites and enzymes and nitrogen shortage reduces plant growth in drought stress conditions (Singh et al., 2005). Phosphorous shortage alters water absorption in plant and largely reduces stomata conductive and subsequently photosynthesis and growth (Farooq et al., 2009). It has been shown that decreasing relative water content may reduce stomata conductive, photosynthesis, CO₂ production, and plant growth in drought stress (Cornic and Fresneau, 2002).

Sanchez-Rodruguze in 2010 studied genotypes in tomato and reported a positive relationship between relative growth rate in the plant and relative water content in leaf. Water shortage in plant environment damages pigments and plastids and reduces chlorophyll and carotenoid in most plants (Fellows and Boyer, 1996). In addition to prevention of water absorption, different nutrients absorption may also be limited in drought stress conditions. Proper nutrition is known as one of the plant production management mechanisms in different environmental conditions (Wariach et al., 2011).

Biological fertilizers and natural inputs in ecosystems are one of the main factors in sustainable agriculture in order to eliminate or reduce chemical elements (Patel et al., 2011). Azomite is an inorganic, 100% natural compound without any additional elements, which has been used in organic agriculture because it is not synthetic and does not have any environmental pollution (Yarrow, 2000).

Tomato (Lycopersicon esculentum M.), belongs to Solanaceae family and is largely cultivated in different regions especially semi dry climates. Irrigation and proper nutrition are environmental factors, which affect production and function of this plant (Wang et al., 2011). The aim of this study was investigating the effects of drought stress and azomite fertilizer on biomass, some of physiological growth indices, chlorophyll, carotenoid, relative water content, nitrogen, phosphorus and potassium content in two tomato cultivars, namely, Izmir and Izabella under greenhouse condition.

Materials and Methods

Plant material and growth conditions

The seeds of two tomato cultivars, Izmir and Izabella, were obtained from Seed and Plant Improvement Institute, Karaj, Iran. The seeds of these cultivars were germinated and grown for 30 days in individual pots (25 cm upper diameter, 17 cm lower diameter, and 25 cm height) and filled with sand, clay, and silt (2:1:1), the soil pH was maintained at about 7.6. All pots were kept in greenhouse under controlled conditions with relative humidity of 65%, at 25±1 °C - 15±1 °C (day/night), and a 16 h/8 h photoperiod with a photosynthetic photon-flux density of 450 μmol m⁻² s⁻¹ (measured with an SB quantum 190 sensor, LICOR Inc., Lincoln, NE, USA). Irrigation was done thrice a week according to soil FC for one month. The water stress and Azomite fertilizer treatments began 30 days after germination and maintained for 25 days. The first group, i.e., control was irrigated according to FC, the second group received mild stress (1/2 FC), and the third group received severe stress (1/4 FC). The control plants received 300 ml water and the mild and severe drought stress treatments involved 200 ml and 100 ml water every 3 days, respectively. Four treatments were tested for Azomite, included the control (0 g/pot), 25, 50, and 100 g Azomite at per pot.
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Estimation of the shoot and root biomass and height

Four replicates of the control and treated plants (four plants in each) were harvested and the shoots and roots of each plant were collected separately for estimation of shoot and root fresh and dry weight and height. The shoot and root biomass and height were expressed as g plant$^{-1}$ and cm shoot and root$^{-1}$, respectively.

Estimation of growth analysis

Three-week-old seedlings were harvested for RGR and NAR calculation before treatments (day 0). After the treatments, plants were randomly selected for the growth analyses and were separated to shoot and root fractions. Shoots were dried at 70 °C for 72h and dry weights were used to calculate the RGR and NAR of shoots according to the method of Hunt et al. (2002).

Chlorophyll and carotenoid contents were determined using Lichtenthaler method (1987). 0.05 g of fresh leaf was extracted in 10 ml 80% acetone (v/v). The absorbance of the extracts were then measured at 663, 645, and 470 nm for chlorophyll a, b, and carotenoid using a UV/visible spectrophotometer (UnicamUV-330, USA). Chlorophyll and carotenoid contents were estimated based on mgg$^{-1}$ FW.

Determination of the relative water content (RWC)

Third leaves (n=6) were obtained from each treatment group and their fresh weight (FW) was determined. The leaves were floated on deionized water for 6h under low irradiance and then the turgid tissue was quickly blotted to remove excess water and their turgid weights (TW) were determined. Dry weight (DW) was determined after the leaves were dried in the oven. RWC was calculated by the following formula (Barrs and Freshherley, 1962):

\[
\text{RWC} = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100
\]
The results showed that the rate of all studied traits significantly reduced compared to control in drought stress condition. Increasing Azomite level significantly elevated fresh and dry weight, RWC, total chlorophyll, carotenoid, nitrogen, RGR, NAR, and increased stem length, phosphorous, and potassium in leaf except for 25g Azomite treatment as compared with control. All the studied traits showed higher rate in Izmir compared with Izabella except phosphorous level in leaf and these higher rates were significant in all studied traits except dry weight in plant (Table 1).

The comparison of the effect of drought stress and Azomite on the studied traits showed the highest rate in the treatment without drought stress and with 100g Azomite and the lowest rate in the treatment with severe drought stress and without Azomite (control). Each trait showed significant changes. In mild stress, increasing Azomite level elevated all the studied traits except...
Tomato under Azomite fertilizer and drought stress

Tomato under Azomite fertilizer and drought stress

Table 3
The interaction of drought stress and cultivar on the studied traits

| Cultivar | Drought stress | Stem length (cm) | Dry biomass (g) | Fresh biomass (g) | RWC (%) | Chlorophyll (mg/g FW) | Carotenoid (mg/g FW) | RGR | NAR | Weight
|----------|----------------|------------------|-----------------|-------------------|---------|----------------------|---------------------|-----|-----|--------
| Control  |                | 17.3 a           | 3.457 a         | 13.555 a          | 83.25a  | 3.066a               | 3.251a              | 0.249a | 61.529 a | 0.898 a | 17.763 a |
| Izabella | mild drought   | 15.8 ab          | 2.569 b         | 10.013 b          | 78.81ab | 2.725 a              | 2.229b              | 0.213b | 55.058 b | 0.618 b  | 12.176 b |
|          | severe drought | 12.0 c           | 1.368 c         | 5.952 d           | 63.11c  | 1.181 c              | 1.133b              | 0.123c | 52.196 b | 0.877 c  | 8.791 d  |
| Izmir    | mild drought   | 15.1 b           | 3.702 a         | 11.622 b          | 83.31a  | 3.643a               | 2.635b              | 0.332a | 56.116 b | 1.599 b  | 14.335 b |
|          | severe drought | 14.7 ab          | 2.120 b         | 9.173 c           | 71.03a  | 1.962 b              | 1.807c              | 0.263c | 54.946 b | 0.752 b  | 9.707cd |
|          | Control         | 10.5 c           | 1.465 c         | 2.711 e           | 50.87d  | 1.903c               | 0.784d              | 0.152c | 45.683ab | 0.245c   | 2.95e    |

Similar letters in every column show the differences are not significant (p<0.05).

Discussion

The results showed that increasing drought stress decreased stem length, dry and fresh weight, RGR, and NAR in both cultivars. Izabella cultivar has shown higher decrease in the studied traits than Izmir cultivar compared to the control in each cultivar. Reduction in water absorption in drought stress conditions decreases intracellular water and turgidity pressure, which subsequently inhibits cell division and development and reduces growth and dry mass storage (Delfine et al., 2002). Sanchez-Rodriguez et al. (2010) reported a decrease in biomass and RGR in tomato plant in drought stress conditions. Sekmen et al. (2014) showed a decrease in NAR, RGR, and dry biomass in cotton plant due to a decrease in leaf area, chlorophyll and photosynthesis and an increase in respiration in drought stress conditions. In the current study, a decrease in RGR rate in Izabella cultivar (84.6%) in comparison with Izmir cultivar (62.5%) in drought stress may indicate that Izmir cultivar is more resistant to drought stress than Izabella cultivar. A decrease in fresh biomass in drought stress could stop growth and development of cells due to a decrease in turgidity pressure (Sankar et al., 2007). In the current study, a higher decrease in fresh biomass in Izabella cultivar (76.6%) compared with Izmir cultivar (59.7%) in drought stress may indicate that Izmir cultivar is more tolerant to drought stress than Izabella cultivar. Higher water conservation capacity in drought stress condition is an important way for adaptation and resistance.
(Selote and Chopra, 2002). RWC is a reliable factor to show hydration rate in plant cells (Sanchez-Rodriguez et al., 2010). Rampino et al. (2006) showed that plant ability to maintain cellular water is one of the most important survival factors in drought stress condition and susceptible and resistant cultivars in wheat can be differentiated based on RWC.

The results showed that using Azomite fertilizer increased stem length, fresh and dry biomass, and RGR and NAR in both cultivars compared to the control. Azomite is a fertilizer full of soluble nutrients in water, which increases auxin level in plant and develops plant roots and absorption of organic elements and water (Palmer and Sharon, 2009). Azomite may increase soil nutrients and its absorbance and thus enhance growth in both cultivars. In this study, increasing Azomite enhanced RWC in both cultivars (Table 1).

Using Azomite increases water content in leaf due to potassium level. Palmer and Sharon (2009) reported that Azomite is considered a natural material as it contains 5% potassium, almost 3% calcium and 1% magnesium. Potassium is an osmotic material, which plays a role in maintaining turgidity pressure and water absorption (Saeedakram et al., 2009). The results showed that increasing drought stress decreases total chlorophyll and carotenoid level in both cultivars. Our results are consistent with those of Ghorbanli et al. (2013) on tomato. Thalooth et al. (2006) reported that in drought stress condition, chlorophyllase and peroxidase functions increased and chlorophyll destroyed more than its synthesis and therefore, chlorophyll level decreased. Carotenoids play a protection role against induced oxidative stress and thus are destroyed (Schutz and Fangmeir, 2001). A decrease in chlorophyll reduces photosynthesis and photosynthetic products and subsequently reduces growth. The current study showed that increasing Azomite enhanced photosynthetic pigments in both.

Azomite contains lots of dioxy silicon (Palmer and Sharon, 2009). Using silicon in corn culture under salinity stress condition increases chlorophyll a and b content and therefore increases membrane permeability and photosynthesis level (Osakabe et al., 2014). The results showed that drought stress decreased nitrogen, phosphorous, and potassium level in both cultivars. It has been shown that in drought stress, absorption and accumulation of N and K elements in cotton shoots significantly decreased (McWilliams, 2003). Lack of phosphorous element in shoots of bean genotypes

### Table 1

The interaction of Azomite and cultivar on the studied traits

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Azomite</th>
<th>Stem length</th>
<th>Dry biomass</th>
<th>Fresh biomass</th>
<th>RWC (%)</th>
<th>Chlorophyll (mg FW)</th>
<th>Carotenoids (mg FW)</th>
<th>N (mg FW)</th>
<th>P (mg FW)</th>
<th>K (mg FW)</th>
<th>RGR</th>
<th>NAR</th>
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<td>12.7</td>
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<td>64.51</td>
<td>1.002</td>
<td>1.679</td>
<td>41.917</td>
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Similar letters in every column show that the difference is not significant (p<0.05).
in drought stress might be due to insignificant movement of phosphate ion (Peuke and Remember, 2004). The relationship between drought stress and Azomite showed that increasing Azomite enhances nitrogen and phosphorous in leaves in mild and severe stress with significant increase in mild stress. Potassium level, however, increased higher in severe stress than mild stress. Azomite contains pentoxide phosphorous and nitrogen with 5% potassium (Palmer and Sharon, 2009). In drought stress conditions, plant roots face lack of water and nutrients such as nitrogen and therefore, nitrogen absorption from soil and its concentration in plant may decrease (Singh et al., 2005). Pinior et al. (2005) reported that phosphorous fertilizers increase water consumption yield and plant growth and increasing soil humidity enhances absorption of this element. Decreasing diffusion resistance level of leaf stomata in the sunflowers treated with potassium ion in drought stress condition increases diffusion and transport of this ion to plant shoots compared to control (Lindhauer et al., 2007). In this study, Azomite may increase absorption and accumulation of ions in plant leaves due to the presence of K, P, and N. Higher accumulation of potassium ion in severe drought stress in comparison with mild stress could indicate the important role of potassium in osmosis regulation (Thalooth et al. 2006).

References


