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DROUGHT STRESS AND THE ROLE OF SALICYLIC ACID IN RELIEVING THE OXIDATIVE DAMAGE AT TOMATO PLANTS

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Abstract

Our study was accomplished in lab conditions at Vegetables Research and Development Station Bacău, aiming to determine the impact of foliar treatment with salicylic acid (SA) over the ability of plants to overcame the water stress. The pot experiment used a randomized block design with four replications and ten plants per variant. Leaves from well-developed plants (30 days old seedlings) were sprayed with 1 mM SA solution until both sides were completely moistened. After treatment application, water regime followed as one set was used as a well-water treatment (WW) and the other set as a drought stress treatment (DS) where the plants were restricted watering for the next 10 days. Results showed that tomato plants treated with salicylic acid and exposed to water stress become more tolerant to drought stress induced oxidative damage than those not treated, the values were comparable to those recorded in WW plants. The extent of water stress injury was higher at non-treated DS plants. The results obtained showed that foliar application of SA stimulated the adaptation of plants, improving water-plant relation, allowing to alleviate the oxidative damage.

Key words*: plant growth, stimulating growth, stress factors, VRDS Bacău.*

INTRODUCTION

The climate is changing faster than some cultivated plant species can adapt, raising uncertainties about the future performance of cultivated vegetables (Lippmann et al., 2019; Pironon et al., 2019; Zsögön et al., 2022). In Romania, results from climate studies show a general trend toward warmer and drier conditions over the last 30 years, with the average annual temperature increasing by 0.3-1.1°C (Mihai et al., 2022).

Stressors such as salinity, drought, temperature extremes, and nutrient deficiencies can have an adverse effect on plants (Mimouni et al., 2016; Kul et al., 2020). Water stress is by far the most important environmental constraint in agriculture (Muñoz-Espinoza et al., 2015), which slows plant growth and development and reduces crop production (Fan et al., 2022). Many factors contribute to a water deficit in plant, and these include among others low rainfall, soil salinity, high and low temperatures and high light intensity. Drought stress often affects plants in both natural and agricultural environments (Salehi-Lisar & Bakhshayeshan-Agdam, 2016; Ojuederie et al., 2019; Seleiman et al., 2021). To reduce the negative effects of drought on their physiology, plants have evolved a number of strategies and a highly coordinated hormonal network that are crucial for this process (Muñoz-Espinoza et al., 2015; Wahab et al., 2022).

Salicylic acid (SA) is produced by many organisms, including plants, and is a water-soluble secondary metabolite and phenolic compound (Souri & Tohidloo, 2019). All plants contain SA which is part of the group of plant hormones (Yusuf et al., 2013).

Several studies have shown that SA, if is applied exogenously, in low doses, increases endogenous levels and improves plant growth and development and can play a key role in relieving as well as reducing plant stress (Dempsey et al., 2011; Lakzayi et al., 2014; Wani et al., 2017; Lefevere et al., 2020; Mardani-Mehrabad et al., 2020; Sharma et al., 2020; Chakma et al., 2021; Aires et al., 2022). Also, foliar applied SA improves photosynthesis, growth, and various other physiological and biochemical features in stressed plants (Wani et al., 2017).

Using biostimulants such as SA is an emerging novel practice to improve crop yield and quality because it regulates various physiological and metabolic processes (Nephali et al., 2020; Sariñana-Aldaco et al., 2020). There is no doubt that plants respond to SA in different ways, but how they respond depends on the cultivar, the environment, and the concentration of SA (Rivas-San Vicente & Plasencia, 2011; Orabi et al., 2015; Kumaraswamy et al., 2019).

Tomato (*Lycopersicum esculentum* Mill.) is one of the vegetables that has recently been added to the list of the world's most important food crops (Endalew, 2020; Shafiwu, 2021). It is an herbaceous annual plant from Solanaceae family grown for its edible fruit. The tomato plant produces yellow flowers, and usually a round fruit, which can be red, pink, purple, brown, orange or yellow (Bergougnoux, 2014; Ho, 2017; Quinet et al., 2019). Romania has a high potential export market for this fruit (Tomescu & Negru, 2002; Nour et al., 2013; Soare et al., 2017;).

Worldwide, drought stress severely limited the tomato crop production (Liu et al., 2021). The drought tolerance of plants can be improved. Is demonstrated that the application of SA can reduce the harmful effects of environmental stress on tomato (Aires et al., 2022).

SA is considered an endogenous regulator, and its role in the mechanisms of defence against biotic and abiotic stress has been documented (Javaheri et al. 2012; Mohamed et al., 2020), but, in tomatoes case, the plants are particularly sensitive to SA treatments (Sariñana-Aldaco et al., 2020). Therefore, the aim of this study was to evaluate the effect of foliar treatment at *L. esculentum*, Bacuni variety, with 1 mM SA on growth characteristics of tomato seedlings under drought stress.

MATERIALS AND METHODS

The experiment was carried out in 2022, at Vegetables Research and Development Station from Bacău in a growth chamber.

Plant material and growth conditions

The seeds of *Lycopersicon esculentum* L. Bacuni variety, was purchased from Bacău Vegetables Research and Development Station. The tomatoes seedlings were uprooted from the germinal bed and transplanted in pots with a 7.8 cm diameter and a volume of 150 mL. The plants were maintained in growth chambers, at an average temperature of 25°C ± 2°C. The soil substrate was represented by peat from NAVARBO with a nutrient content of soluble nitrogen (N) - 163 mg/L, nitrate nitrogen (NO_3-n) - 98 mg/L, Ammonium-N (NH_4-N) - 65 mg/L, soluble phosphorus - P (P_2O_5) - 195 mg/L, soluble potassium - K (K_2O) - 217 mg/L + microelements [(boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn)], with a potential of hydrogen (pH) - 5.5, electrical conductivity (EC) = 31 mS/m (1: 5). The peat granulation was between 0-10 mm. All plants were watered every two days for 30 days after planting the seedlings in pots. On the 30th day after transplanting, the plants were divided into different groups, which we called variants, and treated with 1 mM concentration of SA. The first variant, well water (WW), was the control variant. No treatment with SA was applied and the plants were watered regularly (every 2 days). The second variant was regularly watered and treated with salicylic acid (WW+SA). The stress was imposed by stopping the watering of the plants for a period of ten days after the foliar treatment with SA. Therefore, plants from the third variant were under drought stress (DS) conditions and no foliar SA treatment was applied. In the fourth variant, plants were placed under drought stress conditions and treated with salicylic acid (DS+SA). All plants on the experimental variants were watered on day 11 after foliar treatment application. Plant samples were collected 48 hours after the last watering to evaluate the parameters listed below.

Wilting degree

The leaf wilting index of tomato plants was performed according to the wilting scale established by Mai-Kodoni (MAIK), described by Alidu et al. (2019). In our experiment, the wilting index was determined on the 11th day after the application of the foliar treatment on tomato plants.

Plant measurements

All plants in the experimental variants were watered after collecting wilting index data. After 48 h, biometric measurements were performed: plant height (mm), shoot length (mm), root length (mm), wet weights of shoots and roots (g) and leaf surface represented by leaf area (mm^2), leaf length (mm), leaf width (mm), and the ratio factor between length and width.

Leaf area was measured with the ADC AM350 portable leaf area meter.

RESULTS AND DISCUSSIONS

The results showed that drought stress conditions reduced the growth of tomato seedlings. The foliar application of SA also increased the fresh and dry weight of the roots.

To breed plants with greater stress tolerance, the tomato leaf wilting index is used as a visual indicator of low moisture stress (Pungulani et al., 2013). As shown in Figure 1, the plants most affected by water stress were the DS plants with a wilting index of 70%.

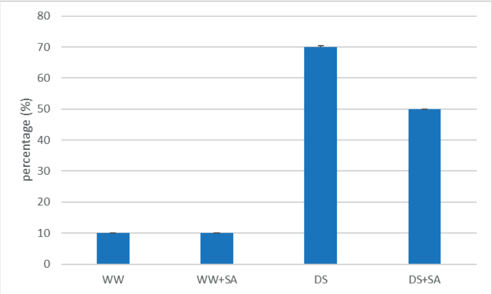

Figure 1. Graphical representation of tomato leaf wilting index means values in day 11 from after SA foliar treatment application

Tomato plants on DS+SA had a wilting index of 50%, which supports the conclusion that treatment with 1 mM SA enhance the resistance of plants to water stress with 20% compared with DS. As a result, the wilting process of drought-stressed plants is obviously slowed down in the DS+SA variant.

Tomato plants showed differences in growth and development according to the experimental variants studied. The SA treatment supported plant growth and development processes under drought stress conditions. The length of plants (Figure 2, blue color) recorded on the DS+SA variant was comparable to those recorded on the control variant (WW).

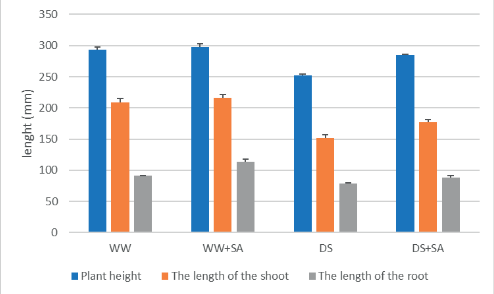

Figure 2. Graphical representation of plant height, shoot length and root length 13 days after SA foliar treatment application

Also, the plants from WW+SA variant recorded higher biometric values compared to the WW control variant. The length of shoots and roots plants from DS+SA variant was higher than plants from DS variant (Figure 2, orange and grey color). We also observe a more uniform growth of plants on the DS+SA variant compared to the other plants grown on studied variants.

Exogenous application of SA has been shown to improve plant growth and development in several studies (Dempsey et al., 2011; Lakzayi et al., 2014; Wani et al., 2017; Lefevere et al., 2020).

In our study the foliar application of 1 mM SA treatment stimulated the growth of tomato plants in both WW+SA and DS+SA variants compared the variants without SA. These results are supported by those of Javaheri et al. (2012) who studied the effects of SA on yield and quality characters of tomato fruit. Foliar application of salicylic acid improves the quantity and quality of tomato fruits (Javaheri et al., 2012).

Also, the foliar application of SA increased shoot and root fresh weight compared to DS and WW. As shown in Figure 3 (blue color), the WW+SA variant has 8.25 g, with a difference of 0.75 g compared to the WW variant. The DS+SA variant has a 7.37 g difference of 0.62 g compared to the DS variant. When it comes to roots (Figure 3, orange color), the differences are smaller, but the mass is higher for variants that have been treated with SA than the variants without SA treatment.

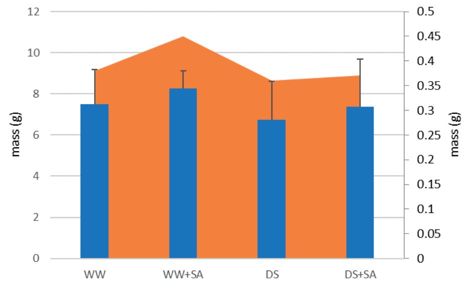

Figure 3. Graphical representation of wet mass of shoots and roots in the experimental variants, 13 days after SA foliar treatment application

Orabi et al. (2015) say that 0.5 mM and 1.0 mM SA treatments have a positive significant effect on growth of tomato plants under low temperature conditions in sandponic culture.

Many studies have shown that the negative impact of heat and water stress can be reduce through the application of SA (Lefevere et al., 2020; Mardani-Mehrabad et al., 2020; Sharma et al., 2020; Chakma et al., 2021; Aires et al., 2022). That's why, foliar surface, specifically LA is a crucial index, indispensable for many physiological models, because LA indicates the rate of photosynthesis, with impact on stress resistance. The results obtained in terms of LA ratio accurately express the relative growth rate changes determined by the stress factors studied. As shown in Figure 4, WW+SA treated variants have the highest LA, leaf length, and leaf width. A higher LA is observed for the DS+SA variant plants compared to the plants from DS variant. Physiological activities of tomatoes are affected by salicylic acid application, which highlights its role in regulating drought stress responses (Javaheri et al. 2012, Chakma et al., 2021, Liu et al, 2021, Fan et al., 2022).

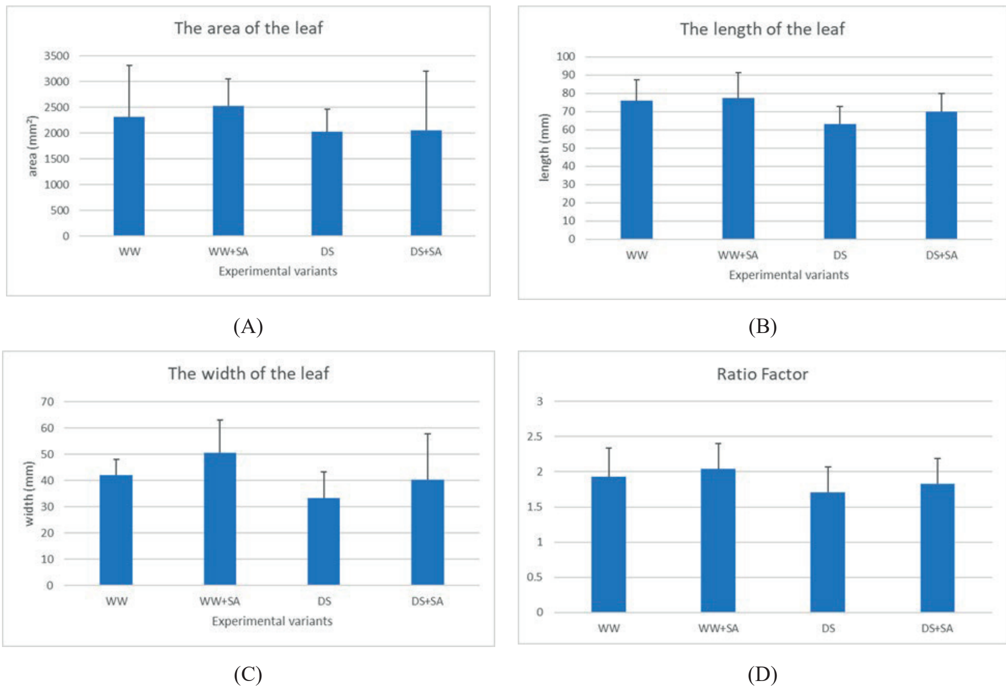

Figure 4. Graphical representation of tomato leaves growth parameters

CONCLUSIONS

Tomato plants wilted quickly and grew poorly in drought circumstances. Foliar application of 1mM salicylic acid (SA) treatment increased tomato seedling development in WW+SA and DS+SA variations when compared to untreated variants. Significant effects were observed on shoot and root length, shoot and root fresh weight, and leaf area. Comparatively to the DS variant, the foliar application of SA at a concentration of 1 mM in the DS+SA variant improved seedling growth. The effects of SA acid treatment on WW+SA variant on tomato seedling is higher than those of the WW control. The foliar application of SA has the potential to control the growth and development of plants cultivated in greenhouses and field, enabling the activation of the plant's response to water stress challenges.

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