Application ZnSO$_4$ on tomato growth under drought stress conditions

A T Sakya$^{1,*}$, E Sulistyaningsih$^2$, B H Purwanto$^2$ and D Indradewa$^2$

$^1$Department of Agrotechnology, Universitas Sebelas Maret, Jl. Ir. Sutami 36 A, Keningan, Surakarta, 57126, Indonesia
$^2$Department of Agronomy, Gadjah Mada University, Jl. Flora Bulaksumur Yogyakarta 55281, Indonesia

Corresponding author: amaliatetrani@staff.uns.ac.id

Abstract. An alternative that can be used to reduce the impact of drought stress is the addition of micro-nutrients, one of which is Zn. Zn application on several plants has been done and showed an increase in the ability of plants to deal with drought stress. However, the application of Zn in drought tomatoes has not been well investigated. Therefore, the research aims to study the application of ZnSO$_4$ on root and shoot growth of drought tomatoes. The study used two factors, namely cultivar ('Tyrana F$_1$' and 'Permata F$_1$') and ZnSO$_4$ doses (0, 10, 20, 30 and 40 mg Zn kg$^{-1}$ soil). The treatments were arranged in factorial based randomized complete block design. Drought conditions are applied by watering through once every eight days. The results showed a different response in a total root length in both cultivars within the ZnSO$_4$ application. ZnSO$_4$ application increased root dry weight; however, there is no different response in the shoot growth of tomato under drought stress. Root dry weight increased 36.8-62.5% on application 20-40 mg kg$^{-1}$ ZnSO$_4$ under drought condition.

1. Introduction
Drought stress is one of the limiting factors for plant growth and yield, including tomato plants. Several studies showed that drought stress on tomato decreased the height, dry weight, the number of leaves, and total leaf area [1–4]. Water stress significantly reduced dry matter production, yield components, and yield in sensitive and tolerant tomato cultivars. The reduction was more significant in drought-sensitive cultivars compared to susceptible cultivars [5–7]. The yield and fruit quality are also factor influenced by the amount of water available to plants. The moisture of 70% field capacity is an adequate water supply for a tomato plant and recommended for better and high-quality yields and fruit size [8,9].

Various strategies have been developed to maintain plant production during drought conditions, besides create drought-resistant variety. Exogenous compounds, such as osmolyte solution, plant regulator, or plant nutrition, are applied in the plant in drought conditions to increase plant resistance to drought [10-15]. For example, using glycine betaine and potassium to improve water relation, and the yield on wheat under drought stress [16] or nitrogen application reduces brassica drought stress [17].

One of the micronutrients used to reduce the damage caused by drought stress is zinc (Zn). Zinc plays a role in various activities of enzymes. It is involved in carbohydrates and protein metabolism,
needed in tryptophan synthesis [12,15], while Zn maintains membrane integrity [12]. Some studies prove that Zn availability could influence plants and water; it also affects stomatal conductivity [19–21]. Zn and Mn spray on safflower (Carthamus tinctorius L.) under the drought stress increase the vegetative growth, seed yield, and seed quality [22].

The information regarding the effect of Zn on the water in limited conditions is more common in food crops and rarely in tomato plants. Hence, this study aims to determine the impact of Zn application on tomato growth in drought stress.

2. Methodology
This research was conducted in the plastic house of the experimental garden of the Faculty of Agriculture, Gadjah Mada University, Banguntapan, Yogyakarta, and Plant Science laboratory of the Faculty of Agriculture Gadjah Mada University. The materials used were tomato seeds (Tyrana F₁ and Permata F₁), fertilizer (urea, SP-36, and KCl), and ZnSO₄·7H₂O (21 % Zn).

The research was arranged in a factorial based on the Complete Randomized Block Design experiment. The treatment of ZnSO₄ doses consisted of 5 levels: 0, 10, 20, 30, and 40 mg of Zn kg⁻¹ soil given to 2 tomato cultivars – Permata F₁ and Tyrana F₁. According to prior studies, both cultivars were efficient and responsive to ZnSO₄. The drought conditions were applied once every eight days of watering. The planting was on polybags with a diameter of 45 cm filled with 8 kg ‘regosol’ soil.

The research included nurseries, planting media preparation, planting, maintenance consisting of fertilization, watering, pruning, weed, pests, and disease control. (1) Nurseries, tomato seeds were sown in planting tray with sand planting media. There were two seeds in each hole. (2) Planting media preparation, the soil was dried and sieved with a 5 mm sieve, then mixed with 10 ton ha⁻¹ compost (50 g polybag⁻¹). Next, 8 kg of soil was poured into polybags with a 45 cm diameter. (3) Planting, the seedling with two leaves was transferred into polybags by inserting into the prepared planting media holes. The planting media was watered until field capacity conditions. (4) Maintenance, including fertilization, watering, pruning, as well as pests and disease control. Fertilization, the fertilizers were SP-36 with a dose of 200 kg ha⁻¹ (0.36 g P polybag⁻¹), given before planting, Urea 200 kg ha⁻¹ (0.45 g N polybag⁻¹), and 100 kg ha⁻¹ KCl (0.1 g K polybag⁻¹), given twice - a week and four weeks after planted, each with 1/2 dose. Watering, plants were watered every other day during transplanting until it got watering interval treatment. Watering interval treatment was performed after the plants adapted to the environment (3 weeks after the transplanting). The watering treatment was performed until the plants were ten weeks after transplanting. Pruning, pruning was performed on shoots that grew on the axilla. Pest control, the pests were caterpillars and were manually controlled with insecticides spray.

Plant characteristics measurement was performed when the plants were ten weeks old after transplanting: root length, root dry weight, leaf area, plant height, total dry weight, and shoot root ratio. The total root length measured utilized the line intersection method, read with the video area meter camera. Leaf area measurement utilized Leaf Area meter. Plant height was measured from base to the tip of the stem. The total dry weight was performed after the plants were dried with an oven under 70 °C for three days and weighed.

The data were analyzed using analysis of variance. Treatments with significant effects were followed by the Tukey test 95% supported by the Minitab program.

3. Results and discussion

3.1. Root system growth
The investigated rooting systems were total root length and root dry weight. Analysis of variance on the total root length shows an interaction between ZnSO₄ and the cultivar used. This fact proves that both cultivars give a different response to the use of ZnSO₄. In the Permata cultivar, the application of ZnSO₄ increases the total root length in drought conditions by 34.5-94.1%. The most significant increase is on the 20 mg kg⁻¹ ZnSO₄, and it is significantly different without the ZnSO₄ application. The different response occurs in Tyrana F₁ cultivar, ZnSO₄ 30 - 40 mg kg⁻¹ escalates the total root
length by around 5.0-18.2%, with the tendency of continuous increase as the increase of ZnSO₄ (Figure 1).

![Figure 1. Total root length of tomato plant in drought stress with ZnSO₄ application](image)

The variance analysis of root dry weight shows no interaction between the level of ZnSO₄ and the cultivar used. However, there is a significant difference between the use of ZnSO₄ and the cultivar used (Table 2). The application of ZnSO₄ from 20 to 40 mg kg⁻¹ significantly increases the root dry weight by 36.8-62.5% compared to without Zn application. The study of root dynamics conducted by Sofianingsih [23] proves that root dry weight in Tyrana F₁ cultivar increases by 57.1-65.4% with 10-40 mg kg⁻¹ Zn application the age of 6 weeks after transplanting.

The effects of Zn on the root growth are frequently reported, but the results are inconsistent. It is expected due to the application of ZnSO₄ increases the Zn concentration in roots, which stimulates the tryptophan synthesis and causes the IAA concentration in the meristem to increase, thereby promoting cell expansion. As explained by Tsui [24] and Cakmak [25] that Zn is actively instrumental in auxin production, which is indicated by the response in increasing IAA content. It causes the growth is faster in the presence of Zn treatment. The increasing root growth is also reported by Gurmani [26] on tomatoes with ZnSO₄ application up to 15 mg kg⁻¹ under normal conditions. Manivasagaperumal [27] also said on green beans that there was an increase in root growth in up to 100 mg kg⁻¹.

### 3.2. Shoot growth

The analysis of variance on plant height shows no interaction between the dosage and cultivar. However, the dosage of ZnSO₄ shows a significant difference. The use of 40 mg kg⁻¹ ZnSO₄ significantly increases the tomato height plant during the drought conditions. The variance analysis on leaf area and plant dry weight also show no interaction between the dosage and the cultivar. In table 1, the application of 30 and 40 mg kg⁻¹ ZnSO₄ increases the leaf area compared to without application by 4.6-6.7%. Yet, the increase has not shown any difference without the ZnSO₄ application. Likewise, for plant dry weight, the use of ZnSO₄ during drought conditions increases the dry weight by 5-9% compared to without the ZnSO₄ application. However, the increase has not shown any difference without the use of Zn during drought conditions.

The statistic analysis on the shoot-root ratio shows no interaction between the dosage and the cultivar used; there is no effect from every single factor. It proves that both cultivars gave the same
responses on root and shoot growth during drought conditions using ZnSO₄. During drought conditions, the increase of ZnSO₄ does not cause differences in assimilating distribution to root and shoot. The shoot-root ratio in drought conditions with the application of ZnSO₄ ranges around 0.19-0.33.

Table 1. The use of ZnSO₄ on the characters of tomato growth under the drought stress at the age of ten weeks old after transplanting

| Treatment | Root dry weight (g) | Plant height (cm) | Leaf area (cm²) | Total dry weight (g) | Shoot-root ratio |
|-----------|---------------------|------------------|-----------------|----------------------|-----------------|
| 0         | 2.13 b              | 64.92 a          | 451.36 a        | 13.39 a              | 0.21 a          |
| 10        | 2.12 b              | 67.92 a          | 398.78 a        | 14.06 a              | 0.19 a          |
| 20        | 2.92 ab             | 65.42 a          | 434.97 a        | 14.66 a              | 0.25 a          |
| 30        | 3.09 a              | 65.42 a          | 481.39 a        | 13.36 a              | 0.33 a          |
| 40        | 3.47 a              | 71.33 b          | 472.26 a        | 14.37 a              | 0.30 a          |

Cultivar

|          | Root dry weight (g) | Plant height (cm) | Leaf area (cm²) | Total dry weight (g) | Shoot-root ratio |
|----------|---------------------|------------------|-----------------|----------------------|-----------------|
| Permata  | 3.65 a              | 68.43 t          | 455.70 t        | 14.12 t              | 0.26 t          |
| Tyrana   | 1.60 t              | 69.57 t          | 439.81 t        | 13.82 t              | 0.25 t          |

Information: Numbers followed by the same letters in the same column show an insignificant difference in the 5% Tukey test.

The increasing plant dry weight because of better development of plant roots and leaves. Hence, the plants could absorb nutrients, water, and capture more energy for photosynthesis in plants applied with Zn. As stated by Cakmak [28], the rise of plant dry weight with ZnSO₄ may be due to the increase of metabolism, auxin biosynthesis, and better nutrients uptake. Increased photosynthesis is thought to be related to the device or activity of various enzymes involved in it. One of the enzymes related to photosynthesis is carbonic anhydrase (CA). This enzyme facilitates the CO₂ diffusion in chloroplasts, and it is a metalloenzyme that requires Zn for its activity [29,30]. Sagardoy [31] reported a stomatal conductivity decrease in Zn excess due to the low number and smaller stomata size.

4. Conclusion
The total root length responses of both cultivars were different on the ZnSO₄ application. ZnSO₄ application increases the root dry weight of drought stress tomato. There is a no different response in the shoot growth of tomato under drought stress with applying ZnSO₄.

References
[1] Nahar K and Gretzmacher R 2002 Bodenkultur 53 45–51
[2] Shao H B, Chu L Y, Jaleel C A and Zhao C X 2008 Comptes Rendus - Biol 331 215–25
[3] Pervez M A, Ayub C M, Khan H A, Shahid M A and Ashraf I 2009 Pakistan J Agric Sci 46 174–8
[4] Sakya A T, Sulistyaningsih E, Indradewa D and Purwanto B H 2017 Sains Tanah - J Soil Sci Agroclimatol 13 74
[5] Rao N, Bhatt R and Sadashiva A 2000 Photosynthetica 38 465–7
[6] Rahman S M L, Mackay W A, Québedeaux B, Nawata E, Sakuratani T and Uddin A S M M 2002 Subtrop Plant Sci 54 16–22
[7] Nahar K and Ullah S 2012 Bangladesh J Agric Res 37 355–60
[8] Nahar K and Gretzmacher R 2011 Acad J Plant Sci 4 57–63
[9] Rizky D 2009 Respon Tanaman Tomat terhadap Frekuensi dan Taraf Pemberian Air. IPB Bogor
[10] Ashraf M, Akram N A, Al-Qurainy F and Foolad M R 2011 *Advance in Agronomy* **111** Elsevier Inc. p 249–96
[11] Manzoor Alam S 1999 *Handbook Plant Crop Stress* ed Pessarakli M Marcel Dekker Inc. New York p. 285–313
[12] Cakmak I 2000 *New Phytol* **146** 185–205
[13] Marschner H 1995 *Mineral Nutrition of Higher Plants*. 2nd ed. London: Academic Press;
[14] Thaithoo L, Tawfik M and Mohamed H 2006 *World J Agric Sci* **2** 37–46
[15] Waraich E A, Ahmad R, Saifullah, Ashraf M Y and Ehsanullah 2011 *Aust J Crop Sci* **5** 764–77
[16] Raza M A S, Saleem M F, Shah G M, Khan I H and Raza A 2014 *J Soil Sci Plant Nutr* **14** 348–64
[17] Xiong X, Chang L, Khalid M, Zhang J and Huang D 2018 *Agronomy* **8** 1–15
[18] Fageria N K 2009 *The Use of Nutrients in Crop Plants* CRC Taylor & Francis Group. Boca Raton
[19] Hu H and Sparks D 1991 *HortScience* **26** 267–8
[20] Sharma P N, Tripathi A and Bisht S S 1995 *Plant Physiol* **107** 751–6
[21] Khan H R, McDonald G K and Rengel Z 2004 *Plant Soil* **267** 271–84
[22] Movahhedy-Dehnavy M, Modarres-Sanavy S A M and Mokhtassi-Bidgoli A 2009 *Ind Crops Prod* **30** 82–92
[23] Sofianingsih D 2015 *Dinamika Pertumbuhan Akar Tomat (Solanum lycopersicum) Kultivar Dataran Rendah dengan Aplikasi Zinc dalam Kondisi Cekaman Kekeringan*. UGM, Yogyakarta
[24] Tsui C 1948 *Am J Bot* **35** 172–9
[25] Cakmak I, Torun B, Erenog B, Marschner H, Kalayci M, Ekiz H and Yilmaz A 1998 *Euphytica* **100** 349–57
[26] Gurmani A R, Jalal-Ud-Din, Khan S U, Andaleep R, Waseem K, Khan A and Hidayatullah 2012 *Int J Agric Biol* **14** 91–6
[27] Manivasagaperumal R, Vijayarenggan P, Balamurugan S and Thiyagarajan G 2011 *J Phytool* **3** 53–62.
[28] Cakmak I, Sari N, Marschner H, Kalayci M, Yilmaz A, Eker S and Gulut K Y 1996 *Plant Soil* **180** 173–81
[29] Sasaki H, Hirose T, Watanabe Y and Ohsugi R 1998 *Plant Physiol* **118** 929–34
[30] Escudero-almanza D J, Ojeda-barrios D L, Sida-arreola J P, Hernández-rodríguez O A, Chávez E S and Ruiz-anchondo T 2012 *Chil J Agric Res* **72** 140–6
[31] Sagardoy R, Vázquez S, Florez-Saras S I D, Albacete A, Ribas-Carbó M, Flexas J, Abadia J and Morales F 2010 *New Phytol* **187** 145–58