THE ROOTS AND LEAVES CHARACTER OF DROUGHT TOMATO ON APPLICATION OF ZnSO$_4$

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ABSTRACT

Application of Zn, beside as an essential nutrient for plants, is known to increase the resistance of plants during drought condition. The purpose of the research was to study the effect of ZnSO$_4$ application on root and leaf character of tomato plants in drought conditions. Research was arranged in factorial randomized completely block design (RCBD). The treatment consists of ZnSO$_4$ application methods (soil and foliar), ZnSO$_4$ dosage (0, 40 and 60 mg Zn kg$^{-1}$) and cultivars ('Permata' F$_1$ and 'Tyrana' F$_1$). Watering interval of twelve days was applied, representing drought stress conditions during the growth period of the plant. The results showed that the all response of character roots and leaves of the tomato did not show interaction among the three factors. Root biomass, root length and root surface area of tomato plants depend on the method of application and ZnSO$_4$ dosage. Soil application increased root biomass and root surface area. The response of ‘Permata’ F$_1$ and ‘Tyrana’ F$_1$ cultivars to the ZnSO$_4$ application manifested in the leaf are did not significantly differ.

Keywords: drought stress, tomato, ZnSO$_4$

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INTRODUCTION

Drought is one of the factors that threaten agricultural products in most parts of the world. The drought has not only caused by the decrease in rainfall that causes plant water shortage, but also may be due to moisture in the soil that cannot be utilized plants. Plants exposed to stress due to decreasing supply of water or other resources, or because of climatic changes, show different responses according to species and the nature and severity of the stress. Almost every plant process is affected directly or indirectly by water supply. Water shortage significantly affects the extension growth and the root-shoot ratio at the whole plant level (Anjum, 2011; Akinci and Lösel, 2012).

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Zn application can be done through the soil, foliar or priming seed. Application through the soil is the most common method to supply essential nutrients for plants. Nevertheless, the existence of drought stress, resulting in reduced absorption of nutrients by plant roots cause a decrease in the rate of diffusion of nutrients from the soil solution to the root surface (Hu and Schmidhalter, 2005). Therefore, foliar application can be an alternative to the application of Zn to correct disadvantages of soil Zn application. Applications through the leaves more effective and allows nutrients are absorbed faster, in addition to the application through the leaves may also address physiological disorders due to nutrient deficiency and can help overcome various abiotic stresses (Fageria, 2009).

Considering the points mentioned above, it is necessary to conduct research on methods of zinc application that can reduce the impact of drought stress, but also to meet the needs of plants. This research is specifically aimed to study the response of roots and shoots of drought tomato plants on ZnSO₄ application.

**MATERIAL AND METHODS**

The experiment was conducted in a plastic house at the Research Farm, Faculty of Agriculture, Gadjah Mada University (UGM Yogyakarta, Indonesia), Plant Science Laboratory UGM Yogyakarta, Physiology and Plant Biotechnology Laboratory UNS Surakarta. Research was conducted from March to August 2014. The experiment was designed using factorial complete randomized block design. The treatment factors were ZnSO₄ (21% Zn) application method, dosage ZnSO₄ and cultivars. ZnSO₄ application methods were foliar and soil application. ZnSO₄ doses were 0, 40, and 60 mg Zn kg⁻¹, and cultivars were ‘Permata’ F₁ and ‘Tyrana’ F₁. Application of ZnSO₄ through the soil was done by sowing on the surroundings of the plant at a week after planting. Foliar applications were done by spraying a solution of ZnSO₄ 1% starting from a week until 35 days after transplanting. Each combination treatment was replicated 3 times. To give the drought condition, the plants were watered every 12 days. The other one tomato was planted in sufficient water by watering every 2 days and without ZnSO₄ application on both cultivars.

The tomato was grown on 1.8 x 1.2 m plot with a spacing of 40 x 60 cm so each plot containing 6 plants. The distances between plots were about 0.5 m and 0.75 m spacing between blocks. Implementation of the research includes: nursery, planting media preparation, planting, maintenance, and harvesting. Maintenance includes fertilizing, watering, pruning, and pest and disease control. The tomato was fertilized by compost 20 tons ha⁻¹ (2.88 kg plot⁻¹), SP-36 200 kg ha⁻¹ (43.2 g plot⁻¹) before planting, also Urea 200 kg ha⁻¹ (43.2 g plot⁻¹) and KCl 100 kg ha⁻¹ (21.6 g plot⁻¹) on 1 and 4 weeks after planting ½ dose respectively.

Measurement of roots and leaf plant was carried out at 12 weeks after planting. Roots and leaves character were total root length, root surface area, root biomass, leaf area, and leaf area ratio. Measurement of total root length and root surface area carried out by the method of intersection of the line that was read by a video camera meter area, as described in Indradewa (2002). Root biomass obtained from drying out the roots with an oven at 80 °C for 48 hours or after obtaining a stable weight. Leaf area was measured using Leaf Area Meter and leaf area ratio is obtained by dividing leaf area with leaf dry weight (cm² g⁻¹) (Amanullah, 2007).
RESULT AND DISCUSSIONS

Root character

The root characters are root biomass, total root length, and root surface area (Table 1). Applications of ZnSO₄ through the soil in drought conditions increase root biomass, root length, and the total surface of root area, while foliar applications of ZnSO₄ those root character are lower comparable than under drought condition without ZnSO₄ application.

In addition, there was an interaction between dosage and application method also between cultivars and ZnSO₄ dosage for root biomass (Table 2). This illustrates that there is a difference response in both cultivars along with increased doses of ZnSO₄. On ‘Permata’ F₁, ZnSO₄ applications up to 60 mg Zn kg⁻¹ soil, increase root biomass, although it did not show significant differences with root biomass of plants under drought condition without ZnSO₄ application.

The results showed that ZnSO₄ application through the roots in drought conditions can improve root growth as indicated by the increase in root surface area and root dry weight. This might be due to an increase in the concentration of Zn in the root which is quite helpful for tryptophan synthesis and affect the concentration of IAA in the meristem is increased, thus induce the cleavage and the enlargement of cells and stimulate the growth of root as explained by Cakmak et al. (1998) that Zn played an active role in the production of auxin.

Table 1. Root biomass, total root length, and root surface area of tomato on 2 and 12 days watering intervals with the application of ZnSO₄

| Method  | Watering interval (days) + ZnSO₄ (mg Zn kg⁻¹) | Mean |
|---------|---------------------------------------------|------|
|         | 2                                          | 12   | 60     |
|         | 0                                          | 0    | 40     | 60     |
| Root Biomass (g) |                                              |      |        |
| Soil    | 23.29 a                                     | 9.32 ef | 13.68 cd | 16.76 c | 15.76 |
| Foliar  | 23.65 a                                     | 10.14 de | 8.64 e-h | 8.94 e-g | 12.84 |
| Mean    | 24.37                                       | 9.73  | 11.16  | 12.85   | (+)    |
| Total root length (m) |                                              |      |        |
| Soil    | 8.54 d-f                                    | 14.57 ab | 16.90 a | 17.03 a | 14.43 |
| Foliar  | 7.72 d-g                                    | 13.21 bc | 10.78 c-e | 11.09 cd | 10.29 |
| Mean    | 7.80                                        | 13.39 | 13.84  | 14.39   | (+)    |
| Surface leaf area (cm²) |                                             |      |        |
| Soil    | 416.48 c                                    | 318.19 e-g | 588.16 a | 547.76 ab | 467.65 |
| Foliar  | 410.61 cd                                   | 336.67 de | 320.80 d-g | 330.98 d-f | 349.76 |
| Mean    | 413.55                                      | 327.43 | 454.48 | 439.37   | (+)    |

Remarks: CV root dry weight = 15.86%, CV root length = 16.47%. CV root surface area = 13.19%. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (+): interactions

Table 2. Root biomass (g) of two cultivars of tomato on 2 and 12 days watering intervals with the application of ZnSO₄

| Cultivar | Watering interval (days) + ZnSO₄ (mg Zn kg⁻¹) | Mean |
|----------|---------------------------------------------|------|
|          | 2                                          | 12   | 60     |
|          | 0                                          | 0    | 40     | 60     |
| ‘Permata’ F₁ | 21.769 ab                                   | 10.333 cd | 9.786 e | 12.723 cd | 13.653 |
| ‘Tyrana’ F₁ | 25.176 a                                    | 9.128 e | 12.535 c | 12.976 cd | 14.954 |
| Mean     | 23.472                                      | 9.731 | 11.161 | 12.849   | (+)    |

Remarks: CV 15.86%. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (+): there is interaction.
Leaf character

Analysis of variance showed that there was no significant interaction of three or two factors, including dosage, method of application ZnSO\(_4\) and cultivars and there were only a ZnSO\(_4\) dose effect against the tomato plant leaf area. Table 3 shows that drought stress decreases leaf area. The addition of ZnSO\(_4\) in drought conditions does not increase of leaf area significantly. In addition, the method of ZnSO\(_4\) application also does not affect the leaf area. Leaf area is 2323.1 cm\(^2\) and 2420.3 cm\(^2\) for 'Tyrana' F\(_1\) and ‘Permata’ F\(_1\), respectively.

Table 3. Leaf area of two cultivars of tomato on 12 weeks age at 2 and 12 days watering intervals with the application of ZnSO\(_4\)

| Treatment                  | Leaf area (cm\(^2\)) |
|----------------------------|----------------------|
| Watering interval (days) + ZnSO\(_4\) (mg Zn kg\(^{-1}\)) |                       |
| 2  | 0  | 3701.3 a |
| 12 | 0  | 1872.5 b |
| 40 | 0  | 1976.8 b |
| 60 | 0  | 1936.4 b |

ZnSO\(_4\) application

| Soil           | 2424.3 a |
|----------------|----------|
| Foliar         | 2329.2 a |

Cultivar

| ‘Permata’ F\(_1\) | 2420.3 a |
| ‘Tyrana’ F\(_1\) | 2323.1 a |

Interaction (–)

Remarks: CV 14.89 %. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (–): there is no interaction.

Table 4. Leaf area ratio (cm\(^2\) g\(^{-1}\)) of two cultivars tomato plants at 6 weeks age after transplanting at 2 and 12 days intervals watering with soil and foliar ZnSO\(_4\) application

| Method | Cultivar       | Watering interval (days) + ZnSO\(_4\) (mg Zn kg\(^{-1}\)) | Mean |
|--------|----------------|--------------------------------------------------------|------|
| Soil   | ‘Permata’ F\(_1\) | 154.47 b 125.03 b-d 108.07 de 86.40 de | 118.49 |
|        | ‘Tyrana’ F\(_1\) | 153.48 bc 99.23 de 112.55 de 83.41 de | 112.17 |
| Foliar | ‘Permata’ F\(_1\) | 119.11 b-d 110.07 de 151.77 bc 80.23 e | 115.29 |
|        | ‘Tyrana’ F\(_1\) | 198.71 a 116.39 c-e 106.88 de 103.08 de | 131.26 |
| Mean   | 156.44          | 112.68 119.81 88.28 (+) |      |

Remarks: CV= 16.97 %. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (+): interaction.
method of application used. On the application through the soil, increasing the dose gives a pattern quadratic which represents an increase of dose ZnSO₄ up to 30 mg Zn kg⁻¹ soil, increase the leaf area ratio of the tomato and an application more than 30 mg Zn kg⁻¹ soil will lower the leaf area ratio of the tomato plant on the condition drought stress. On the contrary, on foliar application illustrates the declining leaf area ratio is linear along with an increasing the rate of ZnSO₄.

Table 5 shows the leaf area ratio of tomato plants at 9 weeks after transplanting differ between the two cultivars depending on the dose ZnSO₄ application. On ‘Permata’ F₁, ZnSO₄ application of drought conditions does not improve the leaf area ratio significantly and also a leaf area ratio of plants was not significant difference between with normal watering and without ZnSO₄ application. However, on ‘Tirana’ F₁, ZnSO₄ application of drought conditions improved significantly over the increased dose of ZnSO₄. Under drought conditions, the highest leaf area ratio of ‘Permata’ F₁, was in the plant without application of ZnSO₄, while the ‘Tyrana’ F₁, the highest leaf area ratio is in plant with 60 mg Zn kg⁻¹ soil application. Differences in both cultivars responses may be due to differences in Zn absorption and Zn efficiency.

The response leaf area ratio of both cultivars at the age of 12 weeks is no difference, but is determined by the dose and application method of ZnSO₄ (Table 6). On the soil application of ZnSO₄, the leaf area ratio of plant under drought condition is lower than the other one without ZnSO₄ application. The leaf area ratio of plant under drought condition with ZnSO₄ application is not significantly different compared by without ZnSO₄. On the foliar application, leaf area ratio of plant under drought condition without ZnSO₄ lower than the leaf area ratio of plants with normal watering without ZnSO₄ application. ZnSO₄ application of drought conditions increases the leaf area ratio significantly. This shows that foliar ZnSO₄ can affect the distribution of biomass and the high value of leaf area ratio in a foliar ZnSO₄

Table 5. Leaf area ratio (cm² g⁻¹) of two cultivars of tomato plants at 9 weeks age after transplanting on 2 and 12 days watering intervals with the application of ZnSO₄

| Cultivar     | Watering interval (days) + ZnSO₄ (mg Zn kg⁻¹) | Mean   |
|--------------|-----------------------------------------------|--------|
|              | 0  | 2   | 40 | 60 | 0  | 2   | 40 | 60 |        |
| ‘Permata’ F₁ | 50.88 b-d | 61.08 ab | 58.95 a-c | 53.96 b-d | 56.22 |
| ‘Tirana’ F₁  | 50.92 b-d | 50.44 b-d | 59.38 ab | 63.43 a | 56.04 |
| Mean         | 50.90 | 55.76 | 59.17 | 58.70 | (+) |

Remarks: CV= 12.59 %. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (+): there is interaction.

Table 6. Leaf area ratio (cm² g⁻¹) of two cultivars of tomato plants at 12 weeks after transplanting on 2 and 12 days watering intervals with soil and foliar ZnSO₄ application

| Method      | Watering interval (days) + ZnSO₄ (mg Zn kg⁻¹) | Mean   |
|-------------|-----------------------------------------------|--------|
|             | 0  | 2   | 40 | 60 | 0  | 2   | 40 | 60 |        |
| Soil        | 38.75 ab | 33.12 a-c | 31.32 cd | 30.71 c-f | 33.48 |
| Foliar      | 35.59 ab | 31.29 cd | 38.96 ab | 43.16 a | 37.25 |
| Mean        | 37.17 | 32.21 | 35.14 | 36.93 | (+) |

Remarks: CV= 15.79 %. Figures in the same row or column followed by the same letter do not differ at 5% Duncan test. Sign (+): there is interaction.
application under drought condition indicates the existence of a competitive position in the plant due to the allocation of a larger biomass into the leaves or because the leaves produces thin leaves with area leaves that higher per dry weight of leaves.

CONCLUSION
1. Root biomass, root length, and root surface area of tomato plants depend on the method of ZnSO₄ application and dosage. Soil application increased root biomass and root surface area.
2. The application of ZnSO₄ 60 mg Zn kg⁻¹ in drought conditions increased the root biomass of ‘Tyrana’ F₁ higher than in the ‘Permata’ F₁
3. The response of ‘Permata’ F₁ and ‘Tyrana’ F₁ cultivars to the ZnSO₄ application manifested in the leaf are did not significantly differ.
4. Response of tomato leaf area ratio to the ZnSO₄ application at each stage of growth was significantly different. The leaf area ratio of tomato on 6 weeks after transplanting depends on dosage and method of ZnSO₄ application and tomato cultivars. The leaf area ratio of ‘Permata’ F₁ and ‘Tyrana’ F₁ for 9 weeks after transplanting show different patterns. The leaf area ratio of tomato on 12 weeks after transplanting depends on the method of ZnSO₄ application.

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