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RESEARCH ARTICLE

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), $ZnS0_4$ 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; Akıncı and Lösel, 2012).

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Mineral nutrient applications can reduce damage from drought stress. Among the micronutrients, zinc (Zn) plays an important role in plant resistance under drought stress. Zinc has a role in maintaining membrane integrity (Cakmak, 2000). Zinc deficiency affects stomata conductivity and transpiration rate (Hu and Sparks, 1991; Sharma et al., 1995; Khan et al., 2004). Zinc plays an important role in the activities of enzymes involved in the metabolism of carbohydrates, proteins and auxin, involved in the integrity of the membranes and protects cells from damage caused by the species of reactive oxygen (Marschner, 1995; Cakmak, 2000; Fagaria, 2009). However, researches into the effects of Zn on the water stress, especially on tomato plants are limited.

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 $ZnSO_4$ 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 $ZnSO_4$ (21% Zn) application method, dosage $ZnSO_4$, and cultivars. $ZnSO_4$ application methods were foliar and soil application. $ZnSO_4$ doses were 0, 40, and 60 mg Zn kg^{-1}, and cultivars were 'Permata' F_1 and 'Tyrana' F_1. Application of $ZnSO_4$ 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 $ZnSO_4$ 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 $ZnSO_4$ 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 (cm^2 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 $ZnSO_4$ through the soil in drought conditions increase root biomass, root length, and the total surface of root area, while foliar applications of $ZnSO_4$ those root character are lower comparable than under drought condition without $ZnSO_4$ application.

In addition, there was an interaction between dosage and application method also between cultivars and $ZnSO_4$ dosage for root biomass (Table 2). This illustrates that there is a difference response in both cultivars along with increased doses of $ZnSO_4$. On 'Permata' F_1, $ZnSO_4$ 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 $ZnSO_4$ application.

The results showed that $ZnSO_4$ 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 $ZnSO_4$

Method	Watering interval (days) + $ZnSO_4$ (mg Zn kg^{-1})				Mean
	2	12			
	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	23.47	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 (cm^2)					
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 $ZnSO_4$

Cultivar	Watering interval (days) + $ZnSO_4$ (mg Zn kg^{-1})				Mean
	2	12			
	0	0	40	60	
'Permata' F_1	21.769 ab	10.333 cd	9.786 e	12.723 cd	13.653
'Tyrana' F_1	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 decrease 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 to 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	1936.4 b
	60	1976.8 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.

The leaf area ratio is one of index that describes the comparison of photosynthetic tissue with the respiratory tissue (Gardner et al., 1991). This index measures of photosynthetic machinery per unit of plant biomass (Amanullah et al., 2007). The results showed that the responses of leaf area ratio to the treatments, there was differ at each stage of growth. At 6 weeks after transplanting, there was an interaction between method, dosage, and cultivars. It shows the leaf area ratio of both cultivars is different and is affected by the dose and application method of $ZnSO_4$. In the next growth phase, the leaf area ratio only affected by the dose of both cultivars $ZnSO_4$ and at 12 weeks after transplanting, the response leaf area ratio affected by the method and dosage of $ZnSO_4$.

Table 4 shows that the leaf area ratio of tomato plants in drought stress is lower than the other one at normal condition, except 'Permata' F_1 with 40 mg Zn kg^{-1} soil application, although it also showed no significant difference. In addition, Table 4 shows the differences in the responses of leaf area ratio both tomato cultivars against $ZnSO_4$ application on drought conditions. On 'Permata' F_1, soil and foliar application of $ZnSO_4$ decrease leaf area ratio, with a greater decline in foliar applications. While on 'Tyrana' F_1 showed the responses of different leaf area ratio on the

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
		2	12			
		0	0	40	60	
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 e	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 $ZnSO_4$ 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 $ZnSO_4$.

Table 5 shows the leaf area ratio of tomato plants at 9 weeks after transplanting differ between the two cultivars depending on the dose $ZnSO_4$ application. On 'Permata' F_1, $ZnSO_4$ 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 $ZnSO_4$ application. However, on 'Tirana' F_1, $ZnSO_4$ application of drought conditions improved significantly over the increased dose of $ZnSO_4$. Under drought conditions, the highest leaf area ratio of 'Permata' F_1, was in the plant without application of $ZnSO_4$, 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 $ZnSO_4$ (Table 6). On the soil application of $ZnSO_4$, the leaf area ratio of plant under drought condition is lower than the other one without $ZnSO_4$ application. The leaf area ratio of plant under drought condition with $ZnSO_4$ application is not significantly different compared by without $ZnSO_4$. On the foliar application, leaf area ratio of plant under drought condition without $ZnSO_4$ lower than the leaf area ratio of plants with normal watering without $ZnSO_4$ application. $ZnSO_4$ application of drought conditions increases the leaf area ratio significantly. This shows that foliar $ZnSO_4$ can affect the distribution of biomass and the high value of leaf area ratio in a foliar $ZnSO_4$

Table 5. Leaf area ratio (cm^2 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 $ZnSO_4$

Cultivar	Watering interval (days) + $ZnSO_4$ (mg Zn kg^{-1})				Mean
	2	12			
	0	0	40	60	
'Permata' F_1	50.88 b-d	61.08 ab	58.95 a-c	53.96 b-d	56.22
'Tyrana' F_1	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 (cm^2 g^{-1}) of two cultivars of tomato plants at 12 weeks age after transplanting on 2 and 12 days watering intervals with soil and foliar $ZnSO_4$ application

Method	Watering interval (days) + $ZnSO_4$ (mg Zn kg^{-1})				Mean
	2	12			
	0	0	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 $ZnSO_4$ application and dosage. Soil application increased root biomass and root surface area.
2. The application of $ZnSO_4$ 60 mg Zn kg^{-1} in drought conditions increased the root biomass of 'Tyrana' F_1 higher than in the 'Permata' F_1
3. 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.
4. Response of tomato leaf area ratio to the $ZnSO_4$ 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 $ZnSO_4$ application and tomato cultivars. The leaf area ratio of 'Permata' F_1 and 'Tyrana' F_1 for 9 weeks after transplanting show different patterns. The leaf area ratio of tomato on 12 weeks after transplanting depends on the method of $ZnSO_4$ application.

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