**MORPHOPHYSIOLOGICAL RESPONSE OF TOMATO CULTIVARS**

 **AT DIFFERENT RATE OF ZnSO4**

**Abstract**

**Background and objective**:Zinc is one of the essential micronutrients for plant growth and development. Although Zn role in various physiological processes of plants has been widely reported, however, has not many reported the role of Zn on the growth, physiology and yield of tomatoes. Therefore the aim of research was to determine the morphophysiological response some tomato cultivar on various dosages of ZnSO4. **Materials and methods:** Research carried out using a complete randomized block design arranged in factorials . The treatment consists of cultivars and dosage of ZnSO4. The seven cultivars tomato used were ‘Mirah’, ‘Zamrud’, ‘Ratna’, ‘Permata’, ‘Tombatu’, ‘Tyrana’, dan ‘Tymoti’. Zn dose consists of 5 levels were 0, 10, 20, 30 and 40 mg Zn kg-1 and applying in the form of ZnSO47H2O. **Results:** The results showed that there is a difference in response between cultivars on the variable root surface area, the nitrate reductase activity, and total biomass; Zn application of 10 mg Zn kg-1 significantly increased root growth, leaf area, fruit weight, chlorophyll content and photosynthesis rate. Increasing the Zn dose from 20 to 40 mg Zn kg-1 did not significantly increase the variables compared with Zn application of 10 mg Zn kg-1.

**INTRODUCTION**

Tomatoes as fruit vegetables are a source of nutrients and secondary metabolites that are important for human health. The nutritional composition of tomatoes in 100 grams is protein (1 g), carbohydrate (4.2 g), fat (0.3 g), calcium (5 mg), phosphorus (27 mg), iron (0.5 mg), Vitamin A (carotene) 1500 SI, vitamin B (thiamine) 60 mg, vitamin C 40 mg. Tomatoes contain lycopene and β-carotene that acts as antioxidants in humans. Consumption of a number of lycopene can prevent cardiovascular disease, prostate cancer and gastrointestinal tract 1,2

For optimum growth and yield, plants including tomatoes require a balanced composition between macro and micro nutrients. Zinc is one of the essential micronutrients for the growth and development of tomato plants3 and based on the need for Zn, tomatoes including the middle category4. Zn deficiency will lead in one or more physiological functions of Zn being not functioning normally thus affecting plant growth. Metabolic changes occurring within plants because Zn acts as a structural component of various enzymes and Zn is also involved in the metabolism of carbohydrates thereby inhibiting the process of photosynthesis5, Zn is also involved in protein synthesis6, Zn deficiency will lead biochemical changes in cell membranes7

 Zn application is rare and only done if symptoms of deficiency appear in plants, so the optimal requirement for growth and yield is not yet known. Considering the above discussion, the purpose of this study was to investigate the application of Zn to the morphophysiological of some lowland tomato cultivars.

 **MATERIALS AND METHODS**

**Experimental location and materials:** The experiment was conducted in a plastic house at the Research Farm and Plant Science Laboratory, Faculty of Agriculture, Gadjah Mada University (UGM Yogyakarta, Indonesia).

**Experimental design:** Research is conducted from April to November 2013. A factorial design in a randomized complete block arrangement with three replications was used to conduct the experiment. The seven lowland tomato cultivars (Mirah’, ‘Zamrud’, ‘Ratna’, ‘Permata F1’, ‘Tombatu F1’, ‘Tyrana F1’, and ‘Tymoti F1 ’ were grown on five Zn dosage (0, 10, 20, 30 and 40 mg Zn kg-1). Zn was given in the form of ZnSO47H2O applied 2 days before transplanting. Tomatoes were planted in polybag filled in mixed Nitrogen (N), phosphor (P) and potassium (K) which were applied in the form of urea, SP-36 and KCl and were given as basic fertilizers of 200, 100 and 100 kg ha-1 respectively. Weeds and insects associated with tomato were managed manually and the watering was done every 2 days.

**Measurement parameters and methods:** Six weeks after transplanting, chlorophyll content, nitrate reductase activity, photosynthesis rate and internal CO2 in leaves were measured on fully expanded leaves.

**Determination Chlorophyl content:** Chlorophyll extraction and analysis were measured as described by Islam et al.8. One g of leaf sample was cut into pieces and crushed in a mortar and then added 20 ml of 80% acetone. The solution was left for a while, then filtered with Whatman no filter paper. 42. The filtrate was put into cuvette until the boundary line and then measured its absorbance by a spectrophotometer at λ 645 and 663 nm. Calculation of chlorophyll content is determined by the formula: Chlorophyll a = (12.7 x A663 - 2,69 x A645) x (20 ml /1000 x 1 g); Chlorophyll b = (22.9 x A645 - 4,68 x A663) x (20 ml /1000 x 1 g) and total chlorophyll = (20.2 x A645 + 8.02 x A663) x (20 ml /1000 x 1 g)

**Estimation of Nitrate reductase activity:** Nitrate reductase activity was analyzed and calculate as described by Hartiko9. Leaf was washed with aquades, and a 1 g of fresh leaves were cut into small pieces and incubated with 5 ml of buffer phosphate solution of 1.2 M, pH 7 for 24 hours in dark condition. After 24 hours, the liquid was removed and incubated again ina new 5 ml phosphate buffer solution and 0.1 ml NaNO3 5 M for 2 hours. Meanwhile, prepared a dye solution of 0.2 ml sulfanilamide 3% reagent dissolved in 3 N HCl and 0.2 ml 0.02% napthylethylendiamide solution into the test tube. After the incubation is complete, the filtrate is taken as much as 0.1 ml and put in a dye tube and waited until it comes out red as a token has been formed nitrite. The solution on the tube, which had been red was removed and placed in cuvet and then measured its absorbance by spectrophotometer 540 nm. The activity of nitrate reductase (µmol NO32- g-1 hour-1)was calculated by the formula:

(Absorbansi sampel / Absorbansi standar) X ( 1000/BB) X ( 1/W1) X ( 50/1000)

 BB = fresh weight (g)

W1= incubation time (jam)

(Hartiko 1991cit Danususilo, 1998).

**Measurement of internal CO2 and Photosynthesis rate:** internal CO2 and Photosynthesis rate and were measured with an infrared gas analyzer (model LI 6400, Licor).

**Morphological characteristics**: the morphological character was determined on 13-week-age include: root length, root biomass, surface root area, leaf area, biomass, and fruit weight

**Data analysis:** Data were statistically tested using an ANOVA test (P0.05) for significance and different treatments was compared using the Duncan test at 5%.

**RESULT AND DISCUSSION**

**Root system**

 The root system is an important part in the plant related to soil nutrient applications and absorption nutrient. Measurements of root system include root biomass, total root length and root surface area. Table 1 showed no interaction between dose and cultivar on root biomass and total root length. This shows that the biomass and root length have the same pattern of increasing Zn dose. The Zn application significantly increases the biomass and root length compared without Zn application. The application of Zn 30 mg kg-1 increases significantly the root biomass and root length compared of 10 mg kg-1 application. The highest biomass is in ‘Tyrana’ F1, while the lowest dry weight is found in ‘Ratna’. Both are significantly different from all cultivars. The root dry weights of ‘Mirah’, ‘Tombatu’, ‘Zamrud’ and ‘Tymoti’ F1 were not significantly different, similarly the ‘Permata’ and Tombatu show not significantly different.

Table 1. Root biomass and total root length of 13-week-age lowland tomato at different ZnSO4 dosage

|  |  |  |
| --- | --- | --- |
| Treatment | Root dry weight (g) | Total root length (cm) |
| ZnSO4 Dosage (mg Zn kg-1) |
| 0 | 3.96 k | 5.74 c |
| 10 | 5.97 j | 7.53 b |
| 20 | 6.09 j | 8.53 ab |
| 30 | 7.69 i | 8.78 a |
| 40 | 8.66 i | 8.13 ab |
| Cultivar |
| ‘Tyrana’ F1 | 9.83 i | 8.70 a |
| ‘Permata’ F1 | 7.91 j | 7.40 a |
| ‘Mirah’ | 6.43 k | 7.75 a |
| ‘Tombatu’ F1 | 6.62 jk | 8.63 a |
| ‘Zamrud’ | 5.66 k | 7.28 a |
| ‘Tymoti’ F1 | 5.20 k | 7.34 a |
| ‘Ratna’ | 3.66 l | 7.16 a |
| CV (%) | 15.19 | 20.47 |
| Interaction | (-) | (-) |

Note: The total root length and the root biomass were transformed by √(x + 0.5). The values followed by the same letter in the same column is not significantly different in the Duncan 5% test. (-). there is no interaction.

There was an interaction between the dosage and the cultivar used on the root surface area. This illustrates that the response of the root surface area of ​​each cultivar differs. The response of varied root surface area to ZnSO4 application among cultivars is clarified in Figure 1. All cultivars. except ‘Tymoti’ show quadratic relationship. but with different quadratic patterns among cultivars. The ‘Tyrana’. ‘Tombatu’. ‘Ratna’ and ‘Mirah’ have a similar quadratic pattern. which illustrates the root surface area increases with increasing of Zn to about 30 mg Zn kg-1. but in the ‘Mirah’ the increase in root surface area is relatively lower than the other three cutivars. Maximum root surface area of 'Permata’ is in ZnSO4 application 10 mg Zn kg-1 and ‘Zamrud’ shows quadratic relationship with very small increase. whereas ‘Tymoty’ shows linear pattern among the root surface area with ZnSO4 application.

Tyrana

y = -0.0495x2 + 2.8235x + 34.921

R² = 0.926 (r = 0.96\*\*)

Permata

y = -0.0333x2 + 0.9897x + 29.645

R² = 0.363 (r = 0.6 \*\*)

Mirah

y = -0.0287x2 + 1.5213x + 4.261

R² = 0.727 ( r = 0.85 \*\*)

Tombatu

y = -0.0427x2 + 2.6803x + 10.03

R² = 0.992 (r = 0.99 \*\*)

Zamrud

y = -0.0115x2 + 0.485x + 24.213

R² = 0.288 (r = 0.54 )

Tymoti y = 0.697x + 13.61

R² = 0.931 (r = 0.96 \*\*)

Ratna

y = -0.0179x2 + 1.3641x + 15.892

R² = 0.840 (0.96 \*\*)

Figure 1. Relationship between ZnSO4 dosage and root surface area at 13 weeks of tomato

The effect of Zn on root growth is assumed because ZnSO4 application increases the Zn concentration in the root which will help increase tryptophan synthesis and the concentration of IAA in the meristem and then stimulate the cell elongation. As described by Tsui10 and Cakmak et al.11 that Zn appears to play an active role in auxin production. this is indicated by the increased response of IAA content faster than growth in Zn treatment. Increased root growth was also reported by Gurmani et al.12 in tomatoes with ZnSO4 applications up to 15 mg Zn kg-1 and Manivasagaperumal et al.13 in *Vigna radiate* in Zn treatment up to 100 mg Zn kg-1.

**Leaf area**

Leaf area data showed that interaction between Zn dosage and cultivar was no significant effect, but the Zn dosage had a significant effect and there was difference of leaf area between cultivars. Table 2 shows that the addition of Zn significantly increased the leaf area of ​​lowland tomato compared with no Zn treatment, but ZnSO4 application by 10. 20. 30 and 40 mg Zn kg-1 doses did not show any significant difference. The widest leaf area is in ‘Tombatu’ and it is not significantly different with Mirah, but leaf area of Mirah is also not significantly different with leaf area of ‘Tyrana’,‘Permata’ and ‘Tymoti’. while the narrowest leaf area is in ‘Zamrud’.

 The increased leaf area due to the ZnSO4 applications because Zn is required in cell division and elongation. Marschner6 states that Zn is necessary in the tryptophan amino acids formation as IAA precursors which are growth regulators for cell elongation. The presence of stunted growth symptoms as well as small leaves in plants deficient Zn. indicates an interruption in auxin metabolism. ZnSO4 application is also thought to increase the activity of various enzymes in photosynthesis so that assimilate is formed more.

**Chlorophyll Content**

Chlorophyll is an important pigment in the process of photosynthesis as a collector of solar energy which will be converted into chemical energy in the process of photosynthesis. There is no interaction between Zn and cultivar on chlorophyll a. chlorophyll b, chlorophyll (a+b) and chlorophyll ratio (a/b), but there is a significant effect of Zn dose and there is a difference of chlorophyll a and total chlorophyll content between the cultivars.

Table 2 shows the chlorophyll content a and chlorophyll (a+b) increased with the increasing ZnSO4 application. The highest content of chlorophyll a and chlorophyll (a+b) were in 40 mg Zn kg-1 application, although not significantly different with dose application of 20 and 30 mg Zn kg-1. The highest chlorophyll b is in 20 mg Zn kg-1 and not significantly different with 30 and 40 mg Zn kg-1. Table 1 also shows no differences in the content of chlorophyll b and the chlorophyll ratio between the cultivars. but the total chlorophyll a and chlorophyll (a+b) content is different. The 'Zamrud' has the highest chlorophyll content (0.315 mg g-1 fresh weight) and significantly differ with others except the ‘Ratna’ and ‘Tymoti’. whereas the ‘Tyrana’ has at least chlorophyll content (0.246 mg g-1 fresh weight). but not significantly different from the others except 'Zamrud’.

Table 2. Leaf area (dm2). chlorophyll content (mg g-1 fresh leaf weight) and chlorophyll ratio some tomato at various doses of ZnSO4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | Leaf area | Chlorophyll a | Chlorophyll b | Chlorophyll (a+b) | Chlorophyll ratio |
| ZnSO4 (mg Zn kg-1) |
| 0 | 17.37 b | 0.144 c | 0.113 k | 0.257 q | 1.315 v |
| 10 | 20.75 a | 0.204 b | 0.159 j | 0.363 p | 1.478 tu |
| 20 | 22.98 a | 0.319 a | 0.190 i | 0.524 o | 1.774 u |
| 30 | 21.77 a | 0.320 a | 0.182 ij | 0.548 o | 1.443 tu |
| 40 | 20.38 a | 0.354 a | 0.172 ij | 0.578 o | 1.625 tu |
| Cultivar |
| ‘Tyrana’ F1 | 19.74 bc | 0.246 b | 0.160 i | 0.407 p | 1.582 t |
| ‘Permata’ F1 | 20.29 bc | 0.257 b | 0.207 i | 0.464 op | 1.328 t |
| ‘Mirah’ | 22.41 ab | 0.249 b | 0.182 i | 0.431 p | 1.493 t |
| ‘Tombatu’ F1 | 28.26 a | 0.271 ab | 0.166 i | 0.437 p | 1.717 t |
| ‘Zamrud’ | 15.19 d | 0.315 a | 0.215 i | 0.530 o | 1.584 t |
| ‘Tymoti’ F1 | 20.23 bc | 0.283 ab | 0.198 i | 0.480 op | 1.455 t |
| ‘Ratna’ | 18.43 c | 0.257 ab | 0.172 i | 0.429 p | 1.581 t |
| CV (%) | 19.27  |  27.96 |  15.18 | 22.43 |  16.77 |
| Interaction |  (-) |  (-) |  (-) |  (-) |  (-) |

Note: The values followed by the same letter in the same column is not significantly different in the Duncan 5% test. (-). there is no interaction.

Zinc is not directly involved in chlorophyll formation. but the effect of ZnSO4 applications on chlorophyll content is suspected because ZnSO4 applications affect other nutrient uptake involved in chlorophyll formation or as part of chlorophyll molecules. such as Mg or Fe. Kösesakal and Ünal14 suggest that Zn may be involved in chlorophyll formation as a regulator of nutrient cytoplastic concentration. Imtiaz et al.15 reported that in Zn deficient plants have higher Fe content than in the sufficient Zn plants. as well Sarmeen et al.15 informed that applying Zn on mung bean increased Mg content and decrease Fe content

Some studies on tomato plants also show an increase in chlorophyll content along with increased Zn applications up to a certain extent. Gurmani et al.12 showed that chlorophyll contains increased with 5. 10 and 15 mg kg-1 Zn of soil ZnSO4 application. Kaya and Higgs17 showed that chlorophyll content of tomato was higher in the application of ZnSO4 through roots (7.7 Zn μmol L-1 in solution) or through roots and leaves at low concentrations (7.7 μmol L-1 in solution and 0.35 mmol L-1 foliar) than without Zn treatment or Zn treatment through roots and foliar at high concentrations (7.7 μmol L-1 in solution and 3.5 mmol L-1 foliar). Similarly. Sbartai et al. 18 stated the addition of low-dose Zn (up to 100 μm) to liquid plant medium. increases chlorophyll content. while the addition of more than 100 μM decreases chlorophyll content.

**Internal CO2 concentration**

The amount of CO2 in the leaves will affect the process of photosynthesis. Table 3 shows the application of ZnSO4 up to 40 mg Zn kg-1 increasing the CO2 concentration of leaves compared with no addition of Zn. The highest concentration of CO2 was found in the application of 30 mg Zn kg-1 and significantly different with no ZnSO4 application and ZnSO4 10 mg Zn kg-1 application. but not significantly different with application of 20 and 40 mg Zn kg-1.

Increasing CO2 concentrations are thought to be related to stomata as the CO2 outlet. with larger stomatal openings so more CO2 present in leaves. According to Sharma et al. 19. the involvement of Zn in the opening of stomata due to the structural role of Zn in the carbonate anhydrase (CA) required to maintain the stability of HCO3- in guard cells and to control the retrieval of K+ by guard cells. Sagardoy et al. 20 reported that there was a decrease in the conductivity of stomata in plants with Zn deficiency due to the low number of stomata.

**Photosynthesis rate**

 Photosynthesis is a biochemical process responsible for almost all the accumulation of dry matter in plants that will determine the productivity of the plant. Table 3 shows an increase in the application up to 40 mg Zn kg-1 significantly increases photosynthesis rate. The highest rate of photosynthesis in ZnSO4 application with Zn 30 mg Zn kg-1 is not significantly different from 20 and 40 mg Zn kg-1. but significantly different from 10 mg Zn kg-1. The highest rate of photosynthesis is in ‘Tymoty’ and is not significantly different from the others. except for ‘Zamrud’ and ‘Ratna’ whereas the lowest photosynthetic rate is in ‘Ratna’ and is not significantly different from the rate of photosynthesis in ‘Zamrud’. ‘Mirah’ and ‘Tombatu’.

Table 3. The internal CO2 concentration (μmol mol-1) and the photosynthesis rate (μmol m-2 s-1) of 8-week-age tomato at various doses of ZnSO4.

|  |  |  |
| --- | --- | --- |
| Treatment | CO2 concentration | Photosynthesis rate |
| ZnSO4 (mg Zn kg-1) |
| 0 | 251.36 c |  94.34 k |
| 10 | 265.33 b | 101.07 j |
| 20 | 266.87 ab | 104.17 ij |
| 30 | 272.29 a | 106.93 i |
| 40 | 268.41 ab | 103.54 ij |
| Cultivar |  |  |
| ‘Tyrana’ F1 | 269.49 a | 106.2 i |
| ‘Permata’ F1 | 264.10 a |  98.5 i |
| ‘Mirah’ | 262.94 a | 102.3 ij |
| ‘Tombatu’ F1 | 265.86 a | 101.5 ij |
| ‘Zamrud’ | 260.13 a | 104.1 j |
| ‘Tymoti’ F1 | 268.34 a | 101.9 i |
| ‘Ratna’ | 263.12 a |  99.6 j |
| CV (%) |  3.56 | 7.39 |
| Interaction | (-) | (-) |

Note: the value followed by the same letter in the same column is not significantly different in the Duncan 5% test. (-). there is no interaction.

 Although the role of Zn in photosynthesis has not been clearly revealed. the increase in photosynthesis is thought to be related to the device or activity of various enzymes involved in photosynthesis. One of the enzymes associated with the process of photosynthesis is carbonic anhydrase (CA). Carbonic anhydrase helps facilitate CO2 diffusion in chloroplasts and is a metaloenzyme that requires Zn for its activity21.22. Research conducted by Pandey et al.23 in black gram (*V. mungo* L. cv. IPU94) showed increasing Zn in planting medium increased the activity of carbonate anhydrase from 32.2 to 91.5 units of enzyme activity along with increased Zn levels in plants from 13.2 to 109.9 μg g-1 dry weight. In addition to carbonic anhydrase. Zn is also a key element of the RuBPC enzyme (1.5-biphosphate carboxylase). an enzyme that fixes CO2 in the early stages of the photosynthesis process 6.4. Salama et al. 24 also identified a decrease in RuPBC activity due to Zn deficiency in maize and chick pea.

**Nitrate reductase activity**

 The enzyme nitrate reductase is one of the key enzymes in nitrate metabolism. There is interaction between Zn dosage and cultivar. it shows that the response of nitrate reductase activity to ZnSO4 application is very varied. Table 4 shows increasing the activity of nitrate reductase on the ‘Permata’, ‘Mirah’, ‘Zamrud’ with increasing ZnSO4 applications. In ‘Permata’, the application of 10 mg Zn kg-1 significantly increased nitrate reductase activity, but subsequent Zn dosing did not significantly different nitrate reductase activity with no ZnSO4 application. In the Mirah cultivars, only a dose of 40 mg Zn kg-1 application significantly improves the activity of nitrate reductase, whereas in the ‘Zamrud’, the application of 20 to 40 mg Zn kg-1 increases the activity of nitrate reductase significantly. Different patterns in the ‘Tymoti’ which shows the application of ZnSO4 decrease of nitrate reductase activity and application of 40 mg Zn kg-1 significantly decrease nitrate reductase activity than without ZnSO4 application. The activity of nitric reductase in ‘Tyrana’. ‘Tombatu’ and ‘Ratna’ showed no difference between those given ZnSO4 applications and not given ZnSO4.

 From some of the literature shows the mechanisms that influence the effect of Zn on the activity of nitrate reductase is not yet clear and still requires in-depth research, but Ghildiyal et al.25 suspected the effect of Zn on the activity of nitrate reductase associated with protein synthesis and RNase. this is based on the observation of decreased activity of nitrate reductase in Zn condition defects in mustard. The decreased activity of nitrate reductase in Zn deficiency was also reported by Seethambaram and Das26 in rice and Pennisetum americanum, while Liu et al. 27 obtained a ZnSO4 application of 5-20 mg Zn kg-1 in wheat increased nitrate reductase activity and optimum nitrate reductase activity was obtained in ZnSO4 application with a dose of 5 mg Zn kg-1, while Luna28 reported a decrease in nitrate reductase activity in Zn High and states that the nitrate reductase is very sensitive to the presence of Zn.

Table 18. The activity of nitrate reductase (μmol NO2-g-1hour-1) of 8-week-age some tomato at various doses of ZnSO4

|  |  |  |
| --- | --- | --- |
| Cultivar | ZnSO4 (mg Zn kg-1) | Mean |
| 0 | 10 | 20 | 30 | 40 |
| ‘Tyrana’ F1 | 1.57 a-f | 0.72 f | 1.25 b-f | 1.43 a-f | 1.98 a-d | 1.39 |
| ‘Permata’ F1 | 1.03 e-f | 1.96 a-d | 1.54 a-f | 1.35 a-f | 1.27 b-f | 1.43 |
| ‘Mirah’ | 2.15 a-b | 1.80 a-e | 1.65 a-e | 2.21 a | 1.08 d-f | 1.78 |
| ‘Tombatu’ F1 | 1.63 a-e | 1.30 a-f | 1.07 d-f | 1.71 a-e | 1.88 a-e | 1.52 |
| ‘Zamrud’ | 0.67 f | 1.57 a-f | 2.03 a-c | 1.75 a-e | 1.34 a-e | 1.47 |
| ‘Tymoti’ F1 | 1.76 a-e | 0.96 e-f | 1.24 c-f | 1.39 a-f | 0.69 f | 1.21 |
| ‘Ratna’ | 1.54 a-f | 1.71 a-e | 1.79 a-e | 1.52 a-f | 1.44 a-f | 1.60 |
| Mean | 1.48 | 1.43 | 1.51 | 1.62 | 1.38 | (+) |

CV = 15. 30.

Description: Data is transformed by √(x + 0.5). The values ​​followed by the same letter in the same column are not significantly different in the Duncan 5% test. (+) there is an interaction

**Total Biomass**

There is an interaction between the Zn dosage and the cultivar on biomass of tomato. Figure 2 shows that the biomass response of different plants among the cultivars. The ‘Tyrana’. ‘Permata’. Mirah’. ‘Tombatu and ‘Ratna’ show a similar quadratic pattern. while ‘Tymoti’ show a quadratic pattern that is opposite to others. and the ‘Zamrud’ tend to have a linear pattern with increased ZnSO4 applications. Pattern differences may be due to the Zn-use efficiency of each cultivar different.

The increase in dry weight of plants is due to better root and plant root developments so that plants are able to absorb nutrients and water and capture energy for more photosynthesis in plants applied with Zn. this is also shown by the increase of rate photosynthesis. so plants applied with Zn are able to produce more assimilates for growth. Cakmak et al.29 stated that the increase in dry weight of plants in ZnSO4 applications may be due to increased metabolism. auxin biosynthesis and better nutrient uptake. Increased plant dry weight was also reported by Wang and Lu30 that in tomato ‘Hulan’ and ‘Zefeng 202’ with soil ZnSO4 application up to 60 mg Zn kg-1.

Tyrana

y = 0.018x2 - 0.1903x + 34.138

R² = 0.95 (r = 0.97\*\*)

Permata

y = -0.016x2 + 1.3379x + 25.56

R² = 0.77 (r = 0.88\*\*)

Mirah

y = -0.0155x2 + 1.2094x + 28.072

R² = 0.97 (r = 0.99\*\*)

Tombatu

y = -0.0193x2 + 1.5193x + 31.274

R² = 0.86 (r = 0.93\*\*)

Zamrud

y= 0.462 x + 28.84

R² = 0.98 (0.99\*\*)

Ratna

y = -0.0127x2 + 0.9694x + 25.108

R² = 0.99 (r = 0.98\*\*)

Tymoti

y = -0.0087x2 + 0.846x + 31.892

R² = 0.93 (r = 0.97\*\*)

Figure 2. Relationship between ZnSO4 dosage and biomass of some lowland tomato

**Fruit weight**

Table 5 shows the application of ZnSO4 increase the fruit weight. however. there is no effect on the number of fruit. Application ZnSO4 more than 10 mg Zn kg-1 increase fruit weight significantly compares without Zn. though. there was no differences between 20. 30 and 40 mg Zn kg-1 dosage. The ‘Tyrana’ produces the highest total weights followed by ‘Tymoti’ that differed significantly from others except 'Permata'. whereas ‘Ratna’ has the lowest fruit weight.

Increasing of fruit weight on ZnSO4 application is suspected because the application of ZnSO4 up to 40 mg Zn kg-1 give a positive effect such as increasing chlorophyll content and photosynthate rate. these will affect to plant growth which further improves the yield component. An increase in the number and weight of fruit per fruit is an important aspect in increasing the weight of fruit per plant. although the application of ZnSO4 to 40 mg Zn kg-1 does not increase the number of fruits per tomato plant. but increases the weight per fruit resulting in increased fruit weight per plant. An increase in fruit weight was also reported by Gurmani et al. 12 on tomatoes ‘VCT-1’ and ‘Riogrande’ with soil Zn treatment up to 15 mg Zn kg-1.

Table 5. The number of fruit and fruit weight of some tomato at various doses of ZnSO4

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Fruit number | Fruit weight/fruit (g) | Total Fruit weight (g) |
| ZnSO4 (mg Zn kg-1) |
| 0 | 13.58 a | 45.47 j | 603.99 p |
| 10 | 14.86 a | 46.94 ij | 669.16 p |
| 20 | 15.38 a | 48.98 ij | 719.49 o |
| 30 | 14.95 a | 49.94 i | 721.91 o |
| 40 | 15.47 a | 49.98 i | 741.63 o |
| Kultivar |
| ‘Tyrana’ F1 | 19.8 a | 47.18 j  | 911.06 o |
| ‘Permata’ F1 | 16.9 a-b  | 44.21 j | 730.91 pq |
| ‘Mirah’ | 10.7 d | 58.71 i | 596.08 r |
| ‘Tombatu’ F1 | 12.3 c-d | 55.78 i | 677.31 qr |
| ‘Zamrud’ | 14.9 b-c | 42.12 j | 616.21 qr |
| ‘Tymoti’ F1 | 18.8 a | 43.76 j | 825.95 op |
| ‘Ratna’ | 10.4 d | 43.27 j | 481.14 s |
| CV | 28.97 | 21.07 | 22.98 |
| Interaction | (-) | (-) | (-) |

Note : Data is transformed by √(x + 0.5). The values ​​followed by the same letter in the same column are not significantly different in the Duncan 5% test. (-):there is no interaction

**CONCLUSION**

1. The response of the surface root area, total biomass and nitrate reductase activity on the application of ZnSO4 depends on cultivars.
2. The biomass response in 'Timothy' and 'Zamrud' shows a different pattern with other cultivars.
3. Zn application of 10 mg Zn kg-1 significantly increased root growth, leaf area, fruit weight, chlorophyll content and photosynthesis rate. Increasing the Zn dose from 20 to 40 mg Zn kg-1 did not significantly increase the variables compared with Zn application of 10 mg Zn kg-1.

**SIGNIFICANCE STATEMENTS**

1. Zn is an essential micro nutrient, however the optimal requirement of Zn for growth and yield of tomato is not yet known.
2. This study is beneficial in presenting the effect of Zn on morphology and physiology character of tomato.