Research Article

Effect of application of potassium fertilizer on the growth and yield of tomatoes at different salinity levels

Nurul Aini*, Wiwin Sumiya Dwi Yamika, Wendy Dwi Andrian, Elok Sukmarani

Department of Agronomy, Faculty of Agriculture, Brawijaya University, Veteran Street, Malang 65145 East Java, Indonesia

*corresponding author: nurulrulyaini@gmail.com

Received 7 May 2019, Accepted 31 May 2019

Abstract: Tomatoes are a horticultural commodity and the main priority to be developed in Indonesia. To improve the production of tomatoes, land expansion is needed. Managing marginal land to grow tomatoes can be an option. Marginal land such as saline land has the potential to be developed as an alternative. This research is aimed to investigate the effect of K fertilizer on the growth and yield of tomato plants at different levels of salinity. The experiment was conducted in a greenhouse located in the rural area of Bendosari in Kediri, East Java, using factorial randomized block design. The first factor was NaCl concentration (0, 3000, 6000 and 9000 ppm) while the second factor was the dosage of ZK fertilizer (75, 150 and 225 kg/ha). The results showed that salinity level reduced growth and yield of tomato while the dosage of ZK fertilizer did not affect. Salinity level on 3000 ppm reduced leaf area 20.35 %, shoot dry weight 27.18%, root dry weight 28 %, number of fruit 24.14 %, fruit weight per fruit 29.82 % and fruit weight per plant 12.42 %. However, salinity level on 6000 and 9000 ppm were not significantly different at all variables except 6000 ppm in leaf area (reduced 37.06%) and 9000 ppm on the number of fruit (reduced 43.01%).

Keywords: K fertilizer, NaCl, salinity, tomato

To cite this article: Aini, N., Yamika, W.S.D., Andrian, W.D. and Sukmarani, E. 2019. Effect of application of potassium fertilizer on growth and yield of tomatoes at different salinity levels. J. Degrade. Min. Land Manage. 6(4): 1883-1888, DOI: 10.15243/jdmlm.2019.064.1883.

Introduction

Tomato is one of the horticultural commodities in Indonesia that are widely cultivated and used as food and raw material for industry. Tomato is the primary income for some farmers and growing tomatoes can potentially improve their earnings. Throughout 2013-2014, tomato production decreased from 992,780 t/ha to 915,987 t/ha per year (Ministry of Agriculture of Indonesia, 2015). Fertile land is continually transformed for non-agricultural purposes, and thus farmers start to convert marginal land, including saline land, into farming areas. Salinity becomes a major problem for many farmers, including those who have land affected by chemical residues and seawater intrusion (Rahmawati, 2013). Salinity is the level of salt dissolved in water. Salinity can refer to the salt contained in the soil. Saline conditions are often found in lowland areas. High concentrations of salt can cause high amounts of Na⁺ to accumulate easily in plant cells, which is toxic at high concentrations (Mathius, 2014). In some cases, a high amount of salts in the soil can cause stunting and anatomical changes in plant organs (Maksimovic and Ilin, 2012). Potassium is one of the critical macro-elements for plant growth because it is involved in some physiological processes such as (1) biophysical processes in its role in controlling osmotic, cell turgor, pH stability, and (2) biochemical processes in its role in the activity of enzymes in synthesizing carbohydrates and proteins as well as increasing photosynthetic translocation (Amisnaipa et al., 2009). Adding K to the soil can neutralize the land from Na stress, and this works for some plants, including tomatoes (Pujiasmanto et al., 2010). Potassium can be absorbed by the plant even in...
saline conditions (Shirazi et al., 2005). Potassium has the potential to support plants to survive under saline conditions.

Materials and Methods

The research was conducted in a greenhouse located in the rural area of Bendosari in Kediri, East Java from April to August 2015. The location is situated at approximately 120 m above sea level with the temperature at 25-29 °C and 1000-1500 mm of rainfall per year. The field experiment was conducted using a factorial randomized block design with two factors and three replications. The first factor is the concentration of NaCl at 0, 3000, 6000, and 9000 ppm, and the second factor is the ZK fertilizer for 75, 150, and 225 kg/ha. Tomato seeds of the Servo F1 variety were soaked with warm water for approximately 15 minutes then sowed in small polybags containing soil and cow manure as the sowing medium. Tomato seedlings were transplanted to a 10 kg polybag containing soil and cow manure as the planting medium, 15 days after sowing. NaCl solution was applied at 14 days after planting and reapplied every two days until harvest time. NaCl was sprayed to the surface of the soil. ZK was applied at 7 days before planting and 35 days after planting. The parameters observed were number of leaves, leaf area, shoot dry weight, root dry weight, total dry weight, number of fruits per plant, fruit weight per plant and per fruit, and sugar content of the fruits. The obtained data were analyzed using Analysis of Variance, then examined with F test at 5 % error level and continued using the Least Significant Difference at 5 % error level.

Results and Discussion

Tomato growth is influenced by some internal factors such as hormone and genetic material as well as external elements such as the environment. Tomatoes need specific conditions to grow optimally. Some environmental conditions such as high salinity can be a severe problem as it can suppress plant growth because it stops protein synthesis. The most common salinity case that is faced by many farmers all over the world is the one caused by NaCl (Sayed et al., 2013).

Number of leaves

Variance analysis revealed that there was a significant effect on the number of leaves due to salinity treatment at 14-56 days after planting (Table 1). Plants not given applications of NaCl had more leaves than those treated with the solution. Increasing the salinity level can decrease the ability of plants to produce more leaves due to hyperosmotic pressure. This causes malfunction of the cell membrane and affects photosynthesis. This condition is also responsible for necrosis of the leaves and a high amount of chloride in leaves and stems (Wibowo et al., 2016). Salinity inhibits leaf growth in correlation with changes in cell size (Hu and Schmidhalter, 2007).

Shoot dry weight, root dry weight, and total dry weight of plants

The variance analysis showed that shoot, root, and total dry weight were affected by salinity condition. The results are presented in Figure 1(a) for the dry weight of the biomass, Figure 1(b) for the dry weight of roots, and Figure 1(c) for the total dry weight.

| Treatment | Number of leaves at certain DAP |
|-----------|----------------------------------|
|           | 14     | 28     | 42     | 56     |
| NaCl (ppm)|        |        |        |        |
| 0         | 13.44 b| 23.11 b| 25.28 b| 26.89 b|
| 3000      | 13.17 b| 18.72 a| 20.28 a| 23.22 ab|
| 6000      | 12.11 a| 16.67 a| 17.94 a| 21.44 a|
| 9000      | 11.67 a| 16.67 a| 18.17 a| 20.28 a|
| LSD 5%    | 0.91   | 2.67   | 4.01   | 3.91   |
| ZK Fertilizer (kg/ha)|        |        |        |        |
| 75        | 12.67  | 20.04  | 21.08  | 23.63  |
| 150       | 12.50  | 18.38  | 20.08  | 22.54  |
| 225       | 12.63  | 17.96  | 20.08  | 22.71  |
| LSD 5%    | ns     | ns     | ns     | ns     |

Remarks: Numbers followed by the same letters are not significantly different based on Least Significance Difference (LSD) test at α 5%, DAP = days after planting, ns = not significant.
Salinity affected shoot, root, and total dry weight of plants at 64 days after planting. Plant without NaCl treatment showed the highest shoot, root, and total dry weight compared to plants treated with NaCl at all levels (3000, 6000 and 9000 ppm). Salinity reduced shoot, root, and total dry weight by up to 31%. Reduced plant dry weight caused by salinity was also reported by Ali and Ismail (2014) on tomatoes by up to a 52% reduction. Plants respond to a salinity condition by creating leaves with a narrow area to avoid water loss and lower the evaporation rate. The salinity condition prevents photosynthesis because the plants are not able to create leaves as large as normal plants, which does not allow optimal energy capture from the sun. Leaves are crucial for plant growth in providing a supply of energy and carbon through photosynthesis (Hu and Schmidhalter, 2007). Lack of water inside the plant body can lead to the closing of stomata. This blocks the flow of CO₂, which is the raw material for the photosynthesis. The low rate of photosynthesis causes the lower dry weight of plants (Usuda, 2004). Plants cannot grow as usual with normal production rate due to the lower photosynthesis rate and lack of water and nutrients for the plants (Wibowo, 2016). The root development is related to the amount of water and nutrition inside the plants. In high salinity conditions, water, which carries nutrients, cannot be transported to the upper part of the plants through osmosis. The high amounts of NaCl in soil inhibits osmosis (Mindari, 2009). Soils with a high amount of sodium (Na⁺) salts (sodic conditions) have additional problems such as poor soil structure, poor infiltration or drainage, and toxicity. This leads to the accumulation of salts in the root zone (United States Department of Agriculture, 2008).

Leaf area

According to Table 5, there was a significant effect of the salinity level toward the leaf area. Plants without NaCl treatment had wider leaves, as much as 27.39% than that given 3000 ppm, 6000 ppm, and 6000 ppm of NaCl. Salinity conditions encouraged plants to produce narrow leaves to lower the evaporation rate and prevent water loss. Consequently, the amount of absorbed sunlight decreases, which will affect photosynthesis.

Number of fruits, fruit weight per plant, and fruit weight per fruit

Salinity level affected the production of the fruits in terms of their weight and its number (Table 5).
Effect of application of potassium fertilizer on growth and yield of tomatoes at different salinity levels

For the number of fruits, plants untreated with NaCl produced more fruit than plants treated with NaCl 9000 ppm, by 43%. The average weight of fruits produced by plants with zero NaCl is higher than fruits generated by plants with 3000 ppm, 6000 ppm, and 9000 ppm by 40.63%. The average weight of single fruits of the control treatment is 15.09% greater than fruits on plants treated with all salinity level of NaCl. The same results were also found in similar research done by Arnanto et al. (2013); Chookhampaeng et al. (2008); Rahmawati et al. (2013); Salama et al. (2012); Yin et al. (2010), who showed that higher salinity level on soil and plants leads to a lower number of fruits produced.

Table 2. Average leaf area, number of fruits per plant, fruit weight per plant, fruit weight per single fruit, and sugar content at various levels of salinity and dosages of ZK fertilizers.

| Treatment          | Leaf Area (cm²) | Number of Fruits per Plant | Fruit Weight per Plant (g) | Fruit Weight per Fruit (g) | Sugar Content (%) |
|--------------------|-----------------|-----------------------------|---------------------------|---------------------------|------------------|
| **NaCl (ppm)**     |                 |                             |                           |                           |                  |
| 0                  | 1186.27 c       | 32.39 c                     | 700.82 b                  | 21.74 b                   | 5.96             |
| 3000               | 945.57 b        | 24.57 b                     | 491.84 a                  | 19.04 a                   | 6.53             |
| 6000               | 747.23 a        | 21.22 ab                    | 405.21 a                  | 17.97 a                   | 6.67             |
| 9000               | 891.39 ab       | 18.46 a                     | 351.11 a                  | 18.36 a                   | 6.50             |
| **LSD 5%**         |                 |                             |                           |                           |                  |
| ZK Fertilizer (kg/ha) |                 |                             |                           |                           |                  |
| 75                 | 1023.38         | 24.08                        | 481.84                    | 18.89                     | 6.34             |
| 150                | 847.97          | 23.89                        | 470.22                    | 18.61                     | 6.40             |
| 225                | 956.49          | 24.51                        | 509.68                    | 20.33                     | 6.51             |
| **LSD 5%**         | ns              | ns                           | ns                        | ns                        | ns               |

Remarks: Numbers followed by the same letters are not significantly different based on LSD test at $\alpha = 5\%$, DAP: days after planting, ns: not significant.

Figure 2. Regression: (a) leaf area and fruit weight per plant; (b) leaf area and fruit weight per fruit, (c) total dry weight and fruit weight per plant and (d) fruit weight per fruit and fruit weight per plant.
Regression analysis (Figure 2) showed a strong relationship between leaf area and fruit weight per plant and per fruit, with regression coefficient of 0.81 and 0.78; between total dry weight and fruit weight per plant with a regression coefficient of 0.88; and between fresh weight per fruit and fresh weight per plant with a regression coefficient of 0.85. These results showed that fruit weight per plant was strongly affected by leaf area, total dry weight and fruit weight per fruit. Salinity can reduce cell development in all parts of plants, including leaves, and it leads to reduced development and differentiation of tissues, unbalanced nutrition, membrane damage, and disturbed avoidance mechanism. This causes a reduction in yield (Ali et al., 2004). Excessive salts transported into the plants causes early senescence due to toxicity (Munns, 2002). This reduces the photosynthetic capability of the plants and affects their yields (Hossain and Nonami, 2012).

Sugar content

Based on variance analysis, both salinity level and ZK fertilizer did not affect the level of sugar content in the fruits (Table 2). Under salinity conditions, plants adjust their metabolism through increasing mineral ion content and compatible solute synthesis for better water uptake (Nemati et al., 2011). With this mechanism, plants can maintain turgor and adjust osmotic pressure; therefore, sugar content remains constant (Morgan, 1992).

Conclusion

The increasing of salinity level in the soil to 3000 ppm decreased the increasing tomato growth and yield. However, increasing salinity to 6000 up to 9000 ppm did not show a significant difference with 3000 ppm. The ZK Fertilizer by dosage up to 225 kg/ha had not been able to increase growth and yield of tomato under salinity condition

Acknowledgement

This research was accomplished with financial support from DITJEN DIKTI for through the Competitive Research Grant Program for Decentralization Research with number: 530.25/UN10.21/PG/2015.

References

Ali, H.E.M. and Ismail, G.S.M. 2014. Tomato fruit quality as influenced by salinity and nitric oxide. Turkish Journal of Botany 38: 122–129.
Ali, Y., Aslam, Z., Ashraf M.Y. and Tahir, G.R. 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. International Journal of Environmental Science & Technology 1 (3): 221-225.
Amisinaipa, A., Susila, D., Situmorang, R. and Purnomo, D.W. 2009. Estimation of potassium fertilizer for tomato cultivation using drip irrigation and polyethylene. Jurnal Agronomi Indonesia 37 (2): 115-122 (in Indonesian).
Arnanto, D., Basuki, N. and Respatijarti. 2013. The test of salinity tolerance on ten genotypes of F1 (Solanum lycopersicum L.). Jurnal Produksi Tanaman 1(5): 415-421 (in Indonesian).
Chookhampaeng, S., Pattanagul, W. and Theerakulpisut, P. 2008. Effects of salinity on growth, activity of antioxidant enzymes and succrose content in tomato (Lycopersicon esculentum Mill.) at the reproductive stage. Scienceasia 34(1): 69–75.
Hossain, M.M. and Nonami, H. 2012. Effect of salt stress on physiological response of tomato fruit grown in hydroponic culture system. Journal of Horticultural Sciences 39 (1): 26–32.
Hu, Y. and Schmidhalter, U. 2007. Effect of salinity on the composition, number and size of epidermal cells along the mature blade of wheat leaves. Journal of Integrative Plant Biology 49 (7): 1016 – 1023.
Maksimovic, I. and Z. Ilin. 2012. Effect of Salinity on Vegetables Growth and Nutrient Uptake. In: Lee, T. S (ed), Irrigation System and Practices in Challenging Environments. In Tech. Rijeka, Croatia, pp 171-173.
Mathius, F.J.M. 2014. Sodium in plants: perception, signalling, and regulation of sodium fluxes. Journal of Experimental Botany 66 (3): 849-858.
Mindari, W. 2009. Salinity Stress and the Effect on Soil Fertility and Plant Growth. UPN Press, Surabaya (in Indonesian).
Ministry of Agriculture of Indonesia 2015. Statistics of Horticultural Production year 2014. Directorate General of Horticulture. Jakarta (in Indonesian)
Morgan, J.M. 1992. Osmotic components and properties associated with genotypic differences in osmoregulation in wheat. Australian Journal of Plant Physiology 19: 67–76.
Munns R. 2002. Comparative physiology of salt and water stress. Plant, Cell and Environment 25: 239–250.
Nemati, I., Moradi, F., Gholizade, S., Esmaeili, M.A. and Bihamta, M.R. 2011. The effect of salinity stress on ions and soluble sugars distribution in leaves, leaf sheaths and roots of rice (Oryza sativa L.) seedlings. Plant, Soil and Environment 1: 26–33.
Pujiasmanto, B., Sumiyati, H. Widijanto, and Alfiatun. 2010. Evaluation of giving legin and K fertilizer on the growth of soybean (Glycine max (L.) Merrill) under NaCl stress. Sains Tanah; Jurnal Ilmu Tanah dan Agroklimatologi 7 (1): 16-24 (in Indonesian).
Rahmawati, H., Sulistyaningisih, E. and Putra, E.T.S. 2013. Effect of NaCl levels on yield and seed quality on tomato. (Lycopersicum esculentum Mill.). Jurnal Penelitian Fakultas Pertanian Universitas Gadjah Mada 1(1): 1-11 (in Indonesian).
Salama, Y.A.M., Hassan, N.M.K., Saleh, S.A. and Zaki, M.F. 2012. Zinc amelioration effects on tomato growth and production under saline water irrigation
Effect of application of potassium fertilizer on growth and yield of tomatoes at different salinity levels

conditions. Journal of Applied Sciences Research 8 (12): 5877-5885.
Sayed, H.E. and Sayed, A.E. 2013. Exogenous application of ascorbic acid for improving germination, growth, water relations, organic and inorganic components in tomato (Lycopersicum esculentum Mill.) plant under salt-stress. New York Science Journal 6 (10): 123-139.
Shirazi, M.U., Ashraf, M.Y., Khan, M.A. and Naqvi, M.H. 2005. Potassium induced salinity tolerance in wheat (Triticum aestivum L.). International Journal Environment Social Technology 2 (3): 233-236.
United States Department of Agriculture. 2008. Soil Electrical Conductivity-Soil Quality Kit-Guide for Educators. USA: USDA.
Usuda, H. 2004. Evaluation of the effect of photosynthesis on biomass production with simultaneous analysis of growth and continuous monitoring of CO2 exchange in the whole plants of radish, cv Kosena under ambient and elevated CO2. Plant Production Science 7 (4): 886-896.

Wibowo, F., Rosmayanti, and Damanik, R.L.M. 2016. Estimation of genetic inheritance of morphological characteristic of F2 crossed of soybean (Glycine max (L.) Merr. under salinity stress. Jurnal Pertanian Tropik 3(8): 70-81 (in Indonesian).
Yin, Y., Kobayashi, Y., Sanuki, A., Kondo, S., Fukuda, N., Ezura, H., Sugaya, S. and Matsukura, C. 2010. Salinity induces carbohydrate accumulation and sugar regulated starch biosynthetic genes in tomato (Solanum lycopersicum L. cv. ‘Micro-Tom’) fruits in an ABA- and osmotic stress-independent manner. Journal of Experimental Botany 61 (2): 563–574.