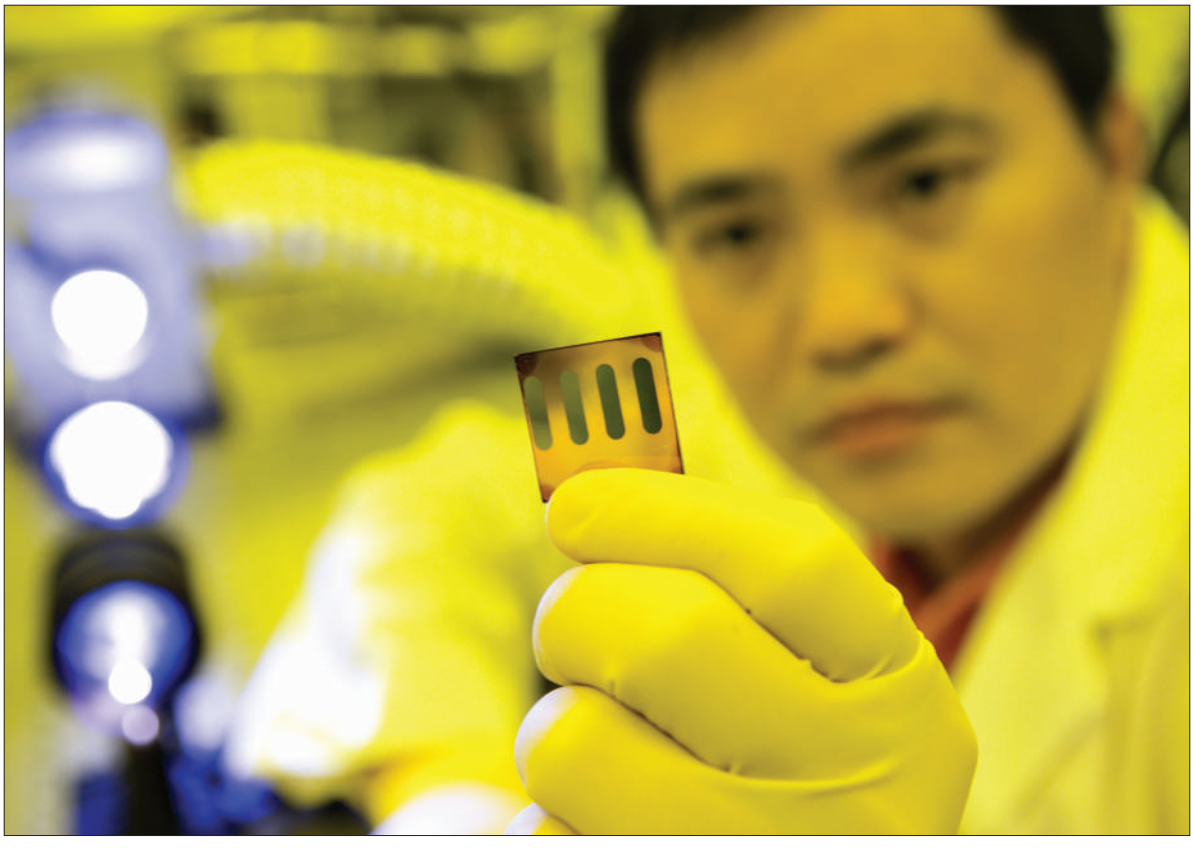

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Research Article
Tolerance of Tomato (*Lycopersicon esculentum* Mill.) On Different Concentration of Aluminum in Simple Hydroponic Wick System

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Abstract

Background and Objective: An acidic soil or salinity soil in Indonesia have distributed in along with of all coastal areas and especially in Sulawesi Island dominantly by Ultisol and Oxisol soil types, resulted in serious problems of plant growth and production. The objective of this observation was to get information about some higher concentration of Aluminum and tomato plant that could be adapted in saline soil. **Materials and Methods:** Five Al treatments in form of different concentrations $AlCl_3.6H_2O$ tested were prepared in water tab solution namely, 0,12,18, 24 and36 mM $AlCl_3.6H_2O$. After 3 weeks of healthy seedlings growth were allocated treatment solution firstly in to the containers and the next was when the solution decreased. One tomato plant was used in each container. The field treatments arrangement were layed out based on completely randomized design (CRD) and each treatment was replicated in 10 times. The observed variables were: plant height, leafy number, leafy length, leafy width, stem diameter, root number, root dry weight, time of flowering, fruit formation, time of dead plant, marketable fruit and fruit weight. All data gathered were analyzed by variance analysis and the mean separation was made by Tukey test at $\alpha = 0.05$ of significance level according to Steel and Torrie's procedure. **Results:** All treatments tested in accordance with observed variables were reduced in their values compared to the untreated one and some of variables values obtained were indicated in the inconsistence patterns, depending on the increasing of $AlCl_3.6H_2O$ concentration. **Conclusion:** The Tymoti variety of tomato plant could be tolerated in higher concentration of $AlCl_3.6H_2O$ over 36 mM in hydroponic system and perhaps containing the salinity tolerant gen(s).

Key words: Aluminum, growth, hydroponic, salinity tolerance, stress, tomato plant, yield

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

An acidic soil or salinity soil in Indonesia have distributed in along with of all coastal areas with around 102.8 million ha and especially in Sulawesi Island there are 9.52 million ha[1]. In Southeast Sulawesi there are 2.3 million ha 60.30% of the total areas and are dominantly by marginal land of Ultisol and Oxisol soil types[2]. The main problems of this soil are the lower pH mostly at 5.0 or lowest, phytotoxicity of vary nutrient heavy metals in higher adsorbed and plant growth stagnation of unavailability of other nutrients[3]. The identical impact of saline soil mainly in negative effect of NaCl on plant growth and production was water deficit stress[4]. From these obstacles probably in particular of the lower pH, an unavailability of plant nutrients would be limited and the plant growth could be stagnated and production will be lowered and perhaps the plant may be dead.

Nutrients toxicity like NaCl, $NaSO_4$, $CaCl_2$, $MgSO_4$ and $MgCl_2$ are the most probable problems in many crop plants sown in acidic soil[4,5]. There are 2 situations in which the conditions became problem in good plant growth and production, firstly in ion exclusion that is excluding Na^+ and Cl^- particularly from leaves and relying on organic solutes for osmotic adjustment and secondly in tissue tolerance means that in accumulating sufficient Na^+ and Cl^- to balance those in the soil solution but having strict ionic regulation in various cell compartments[6]. The NaCl toxicity in particular is the main problem in this research observation due to its negative effect during in whole growth and production of tomato plant. With these soil areas conditions, the potential to manage for agricultural plantation in wide range of crop plant types is most promising effort mainly in horticultural plant type, like tomato plant.

In general, problem solving of these soil obstacles of acidic soils is using the tolerant plant, or plant containing the tolerant gene(s) that coding to NaCl sensitivity so that this tolerant status would be permanently expressed. Implementation of tolerant plant that have permanent gene(s) to saline soil was achieved by vary of breeding technique and biotechnological ways[7]. One of many technique available is the use of conventional breeding by chemical mutation technique namely selection procedure after the plant materials were exposed to several Al (Aluminum) or other saline chemical component treatments until some higher concentration in the growing medium during experiment[8]. Hopefully, some plants that continuously grown and yielded to the end of observation were gathered and these plants would be tolerant to Al or saline soil as a result of gene(s) contained in the whole body of the plant. All of observations were assigned to rise a plant that could be continuously grew and yielded in the higher concentration of some chemical component caused the saline soil.

The tomato plant as research plant material in this observation was used because of several research earlier have used this plant in several different methods and objectives. Jan *et al.*[3] studied the impact of saline-alkali stress on the accumulation of solids in tomato fruit[4] in observing of non-circulating hydroponic methods for growing tomatoes, Islam *et al.*[6] studied the nutrient and salinity concentrations effects on quality and storability of cherry tomato fruits grown by hydroponic system and Mattson and Peters[8] investigated a recipe for hydroponic success. The variable measurement observed of the tomato plant was mainly the fruit solid for quality improvement[4] and soluble sugar and organic acids being the major soluble solids, contribute about 70% to the total solid content of fruits [9,10]. While the other plants were *Cucumis* species by Irmaileh *et al.*[5] and rice by Reddy *et al.*[11] and Gregorio *et al.*[12]. All of researchers were focussed on using the complete hydroponic system on their research with various methods[4-6,8].

This research was aimed to evaluate use of simple non-circulating wick hydroponik system on plant growth and yield of marketable fruits in the higher concentration of stressed aluminum as an effort to obtain the soil tolerant tomato plant that perhaps containing the tolerance gene(s).

MATERIALS AND METHODS

Location and experimental materials: The observations was done at Field Experimental Station II, Faculty of Agriculture, Halu Oleo University, Anduonohu Campus, held on July-September, 2019. The Tymoti variety of tomato seeds plant, mineral water bottles as plant containers, wick as hydroponic solution transfer, small plastic tray as seeding growth preparation, rockwool as seedings medium and chemical constituents of mixed nutrient AB were used as materials experiment. The transparent white plastic was used as house roof to protect the leaching medium solution from rain water and some kinds of non-metal materials for experimental house installation. Specific agricultural tools for gardening were used as well.

Field experimental procedure and design: Six Al treatments in form of $AlCl_3.6H_2O$ tested were prepared in water tab solution namely, 0,12,18, 24 and36 mM $AlCl_3.6H_2O$. After 3 weeks of healthy seedlings growth were allocated treatment solution firstly in to container according to experimental

tested and the next treatment allocation was executed when the solution have been decreased. One tomato plant was used in each container. Weed management was controlled by physical way and insects and pests running were controlled by chemical means. The treatments arrangement in the field of experimental plastic house were layed out based on completely randomized design and each treatment was replicated in 10 times.

Research variables: Those observed variable were: plant height, leafy number, leafy length, leafy width, stem diameter, root number, root dry weight, time flowering, fruit formation, time of dead plant, marketable fruit and fruit weight.

Statistical analysis: All data gathered were analyzed by variance analysis, then continuously to mean separation by Tukey test at $\alpha = 0.05$ of significance level according to Steel and Torrie'sprocedure[13]. These recorded data were managed by statistical package[14] of SPSS version 16.0.0.

RESULTS AND DISCUSSION

These observation was splitted in to two different phases i.e. variables in vegetative and generative growths. This was due to the possibility to understand and explain whether the Al concentrations are either affected in vegetative or in generative phase. Both phases will be mentioned and explained in the next expression under each subheadings. In the vegetative variables (Table 1) those were: plant height (cm), number, length (cm) and width (cm) of leafs and diameter (cm), number and dry weight (g) of roots. Whereas, the generative variables (Table 2) were: flowering time (DAT = days after treated), fruit formation (DAT), time of dead plant (DAT), harvest able fruit (g) and fruit weight (g).

All observed variables in vegetative phase were significantly different according to Tukey test at $\alpha = 0.05$ confidence level. The variability of Al treatments tested were indicated the decreasing values of each variables compared to without $AlCl_3.6H_2O$. These means the existence of $AlCl_3.6H_2O$ in medium or hydroponic media solutions was negative effects on all observed variables. The leaf length and width, stem diameter and root dry weight were the variables that only slightly level to decreased, while the leaf number was deceased in half value and the plant height and root number were also decreased in almost of half number.

Based on $AlCl_3.6H_2O$ treatment, the 12 mM was the lowest values obtained for all observed variables, meanwhile the other treatments were inconsistenced values. Almost all of variables in the higher concentration namely 36 mM of $AlCl_3.6H_2O$ were higher than the lower concentrations. By these data, the effect of aluminum in this exploration was affective the observed variables mainly in vegetative measures in lowering their measurement values and the tomato plant of Tymoti variety still a life until in the end of the experiment.

Table 1: Effect of Al concentration on several vegetative phase traits of tomato plant Tymoti variety after 8 weeks of experimental observation

	Observation after 8 weeks of treatment						
Treatments	Plant height (cm)	Leaf number	Leaf length (cm)	Leaf width (cm)	Stem diameter (cm)	Root number	Root dry weight (g)
0 mM	83.45^{a}	10.60^{a}	12.68^{a}	7.27^{a}	0.70^{a}	8.30^{a}	0.69^{a}
12 mM	37.15^{c}	5.30^{b}	6.39^{c}	4.46^{b}	0.54^{c}	6.20^{c}	0.32^{b}
18 mM	53.00^{b}	5.66^{b}	10.85^{b}	5.10^{ab}	0.66^{ab}	8.66^{a}	0.56^{b}
24 mM	61.08^{b}	5.50^{b}	11.19^{b}	5.33^{ab}	0.68^{ab}	7.66^{ab}	0.86^{a}
36 mM	52.25^{b}	5.50^{b}	11.27^{b}	5.24^{ab}	0.60^{bc}	6.75b^{c}	0.52^{b}
HSD	6.13	1.60	2.40	1.81	0.70	1.10	0.24

Mean values within a column with the same superscript letter are not significantly different according to Tukey test at $\alpha = 0.05$ confidence level

Table 2: Effect of Al concentration on several generative phase traits of tomato plant Tymoti variety after 8 weeks of experimental observation

	Observation after 8 weeks of treatment				
Treatments	Time flowering (day after treatment)	Fruit formation (day after treatment)	Time of dead plant (day after treatment)	Marketable fruits (g)	Fruit weight (g)
0 mM	6.90^{a}	16.40^{a}	50.00^{a}	2.40^{a}	9.28^{a}
12 mM	3.70^{a}	0.00^{c}	50.00^{a}	0.00^{c}	0.00^{b}
18 mM	6.50^{a}	2.30^{c}	37.00^{a}	0.00^{c}	0.22^{b}
24 mM	6.00^{a}	11.00^{b}	42.00^{a}	0.40^{b}	0.21^{b}
36 mM	4.50^{a}	2.20^{a}	36.00^{a}	0.10^{b}	0.17^{b}
HSD	4.00	7.82	33.22	0.38	2.27

Mean values within a column with the same superscript letter are not significantly different according to Tukey test at $\alpha = 0.05$ confidence level

Fig. 1: Roots performances after Aluminum ($AlCl_3.6H_2O$) treated
A_0: 0 mM, A_1: 12 mM, A_2: 18 mM, A_3: 24 mM, A_4: 36 mM

Some similar observations have reported the inline results as showed in this report. Mohammad *et al.*[15] and Surapu *et al.*[16] have reported that the use of 50-150 mM and 100-500 mM NaCl, respectively, were affected the reduction of vegetative growth of tomato plant. The use of 50-150 mM of NaCl indicated that the increasing salinity stress was accompanied by significant reductions in plant height and number of tomato leaves per plant, whereas the use of NaCl in 100-500 mM have also reducing the 40-80% of plant growth. There was no different result have shown the increasing vegetative growth of tomato plant as NaCl or other saline soil causes in the solute solution or grown medium used. Contrasting to another observation, the variable which increasing due to the use of variable NaCl were the high fruit solid content[4,17-20].

The variables that included in the generative phase in this observation were time flowering, fruit formation, time of dead plant, harvest able fruits and fruit weight (Table 2). Three of 5 observed variables were significantly different i.e., fruit formation, harvest able fruit and fruit weight, meanwhile the 2 remained variables namely time of flowering and dead plants were not significantly different. Four aluminum treatments resulting the same effect in time flowering, time of dead plant and fruit weight but the different effect were indicated in fruit formation and harvestable fruits. The values of these observed variables were also showed the inconsistences pattern as showed in the vegetative one. All observed variables in this generative phase showed also the negative effect of $AlCl_3.6H_2O$ on yielding of tomato plant particularly in Tymoti variety.

The similar results have shown that the generative variables measured were also commonly reduced. The number of marketable fruits and the number of fruit formed were lower than the untreated or without Al in the hydroponic solution. Ashraf[21] have shown that the inclusion of saline soil causes in growth solution could be reduced the generative or reproductive components like marketable fruit and fruit yield during the hydroponic observation. Other result by Kochian[22], Barcelo and Poschenrieder[23] and Cuartero and Fernandez-Munoz[24] has reported that the yield component of tomato plant after stressed in hydroponic system with Aluminum was reduced.

Another interesting indication that could be considered in this experiment was the performances of roots morphology (Fig. 1). An untreated with $AlCl_3.6H_2O$ was shown the normal growth, i.e., the length and the composition of the roots, whereas the increasing concentration of treated were grown decreasingly from the almost normal to non-normal phenotype. This was similar to several reports by Rodriguez *et al.*[25], Hajiaghaei-Kamrani *et al.*[26] and Shimul *et al.*[27] in which the performances of roots obtained were inline with in this observation. Another similar expression was pointed out by Borowski and Nurzynski[28], Van Ieperen[29] and Sato *et al.*[30] decrease in morphology, length, composition and numbers of roots reported when the treatment concentration were increased.

CONCLUSION

Either vegetative or generative phase were affected by $AlCl_3.6H_2O$ in simple hydroponic wick system. All observed variables were reduced in their values compared to the untreated. The higher the $AlCl_3.6H_2O$ concentration in the solution medium, the lower the value of all observed variables. Up to the 36 mM of $AlCl_3.2H_2O$ concentration indicates the growth and yields of the tomato plant and these perhaps would contain the tolerant factor(s).

SIGNIFICANCE STATEMENT

This report provides results of a study on effect of saline soil particularly caused by Aluminum in soil solution on tomato plant of Tymoti variety growth and production. Results generated here will eventually help tomato breeders use the $AlCl_3.6H_2O$in mimic saline soil in the field as stressed simulation to form tolerant variety in breeding. The results presented give indication of appropriate use of $AlCl_3.6H_2O$ in generating the new superior varieties of tomato.

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