Relationships between sodium adsorption ratio and water productivity of tomato plants affected by NaCl applications at different growth stages

N Nurlaeny1*, T M Onggo2, M Arifin1, D Herdiyantoro1 and A Setiawan1

1Department of Soil Science and Land Resources, Agriculture Faculty, Universitas Padjadjaran, Jl. Raya Bandung - Sumedang Km. 21 Jatinangor 45363 phone: (+62) 227796316; Fax: (+62) 22 7796316 West Java – Indonesia.
2Department of Agronomy, Agriculture Faculty, Universitas Padjadjaran, Jl. Raya Bandung - Sumedang Km. 21 Jatinangor 45363 phone: (+62) 227796316; Fax: (+62) 22 7796316 West Java – Indonesia.

1E-mail: nenny@unpad.ac.id; tinong2002@yahoo.com; mahfud.arifins@unpad.ac.id; d.herdiyantoro@unpad.ac.id; ade.setiawan@unpad.ac.id

Abstract. Under greenhouse condition, tomato plants (Lycopersicon esculentum Mill. cv. Umagna) were planted in the polybags containing a mixture of soil and charcoal husk with a ratio of 2:1 (v:v) and factorial randomized block design was used in this experiment. Four levels of NaCl concentrations (0; 500; 1000 and 2000 mg kg\(^{-1}\), respectively) and three stages of plant growth i.e. vegetative stage (2-4 weeks after transplanting, WAT); generative stage (5-12 WAT) and vegetative until generative stages (2-12 WAT) with three replications. Seedlings of grafted beef tomato cv. Umagna with rootstock of Rampart cultivar at the age of 40 days after transplanting (DAT) were planted in the polybags. Plants were initially watered until the field capacity, then each NaCl concentrations of 200 mL polybag\(^{-1}\) were given at weekly intervals of 2-4 WAT, 300 mL polybag\(^{-1}\) at 5-8 WAT, and 400 mL polybag\(^{-1}\) at 9-12 WAT in combination with freshwater. Application of 2000 mg kg\(^{-1}\) NaCl significantly affected electrical conductivity (EC), water content and organic C, exchangeable Na\(^{+}\), Cl\(^{-}\), Ca\(^{2+}\), Mg\(^{2+}\) and sodium adsorption ratio (SAR) of soil mixed media. The negative correlations between SAR and water productivity (WP) of tomato (\(r = 0.37-0.89\)) are caused by NaCl applications at different growth stages.

1. Introduction

Beef tomato (Lycopersicon esculentum Mill. cv. Umagna) is the fruit of indeterminate tomato plant, which has a larger size and meaty texture, contains several kinds of vitamins and minerals, and other organic compounds that are beneficial to human nutrition and health (Tang et al., 2008). However, to increase tomato production in the tropics a number of biotic and abiotic factors still a major obstacle that can influence the number and quality of plant yield [1].

Rapid water evaporation, inadequate and highly variable rainfall induces to soil salinization so that concentrations of nutrients in the soil become unbalanced due to the low osmotic potential in soil solution [2]. Furthermore, high atmospheric temperatures and level of humidity in the tropics cause the environment too suitable for proliferation of soil-borne pathogen such as Meloidogyne spp and Fusarium oxysporum f. sp. lycopersici [3].
One of the strategies to alleviate the soil-borne pathogen attacks is by applying NaCl salts. [4] revealed that changing the value of soil pH due to a salt application would affecting the availability of plant nutrients, but it could be as one of the factors which can suppress disease incidence of Fusarium. Chloride molecule is thought to have an important role in those mechanisms [5]. On the other hand, the relative risk of soil damage due to NaCl is shown by Sodium Adsorption Ratio (SAR), which is the relationship between Na\(^+\) concentration compared to the combined concentrations of Ca\(^{2+}\) and Mg\(^{2+}\) ([6]. According to [7] sodium status was a key in determining the water absorption and plant root growth environment.

In fact, the availability and use of water, as well as the supply of nutrients by plants are also influencing factors that affect plant growth and yield production. To determine the relationship between the volume of water needed during the entire period of plant production to produce one kilogram of fresh yield, [8] state that water productivity (WP) can be used in the assessment of the effectiveness of the production systems as a whole. Therefore, to reveal the relationship between SAR of soil mixed media with the WP of beef tomato plant (*Lycopersicon esculentum* Mill. cv. Umagna) was the purpose of this research based on soil physicochemical and fruit yield parameters after the application of various NaCl concentrations at different growth phases.

### 2. Materials and Methods

The study was conducted in a greenhouse (32\(^\circ\)C of daily temperature and relative humidity varied from 73.4\% to 91.2\%). Seedlings of beef tomato (*Lycopersicon esculentum* L. cv. Umagna) with rootstock of Rampart cultivar (endurance of soil infectious disease obtained from Rijk Zwaan Seeds Ltd., De Lier, The Netherlands) were grafted at 28 days after planting (DAP).

A mixture of soil (Inceptisols) and charcoal husk with a ratio of 2:1 (v:v) in one-gallon black plastic (polybag) was used as growing media. One grafted of tomato seedling cv. Umagna at the age of 40 days after transplanting (DAT) was planted in each polybag contained 10 kg of soil mixed media. Fertilizers of urea, superphosphate, calcium sulfate, dolomitic lime were respectively given as N 600 mg kg\(^{-1}\); P 600 mg kg\(^{-1}\); K 240 mg kg\(^{-1}\); Ca 1012 mg kg\(^{-1}\); 309 Mg mg kg\(^{-1}\) and S 500 mg kg\(^{-1}\) to support the plant’s growth.

#### 2.1. Design of experiment

A factorial randomized block design was performed in this experiment using two factors and three replications. The first factor was NaCl concentrations (K) consisting of four levels i.e. k\(_1\) = 0 mg kg\(^{-1}\); k\(_2\) = 500 mg kg\(^{-1}\); k\(_3\) = 1000 mg kg\(^{-1}\); and k\(_4\) = 2000 mg kg\(^{-1}\). The second factor was plant growth stage (S) consisting of three levels, i.e. s\(_1\) = vegetative stage (2-4 weeks after transplanting, WAT); s\(_2\) = generative stage (5-12 WAT) and s\(_3\) = vegetative until generative stages (2-12 WAT).

In each of the treatment row, one polybag without any plant was placed as the representative and watered until field capacity to monitor the evaporative water loss by daily weighing at 7:00-8:00 AM using an electronic weighing device. All sample plants were initially watered until field capacity thereafter NaCl concentration of 200 mL polybag\(^{-1}\) was applied weekly at 2-4 WAT, 300 mL polybag\(^{-1}\) at 5-8 WAT, and 400 mL polybag\(^{-1}\) at 9-12 WAT until the weight of each field capacity was reached by referring to the representative polybags. In addition to weighing, graduated cylinder 250 mL and 1L of beaker glass were used to measure the amount of water given. Before watering, soil mixture media in each polybag was weighed. The amount of water to be given was calculated as:

\[
\text{Irrigation water (L)} = \frac{\text{Wfc}-W\text{pw}}{1-lF} \\
\text{Wfc-W/pw} \\
\text{1-lF}
\]

where at field capacity, Wfc is the weight of soil mixed media in each polybag (kg); W is soil weight in each polybag (kg) before watering; pw is water density (1.0 kg L\(^{-1}\)); the leaching fraction (IF = 0.20) [9].
2.2. The measurements

2.2.1. Physicochemical properties of soil mixed media

The samples of soil mixed media were taken at 8 WAT and analyzed for the parameters of its physicochemical properties (EC values, water content and $C_{org}$, the exchangeable ions of $Na^+$, $Cl^-$, $Ca^{2+}$, $Mg^{2+}$ and SAR [10]. Water content was measured using analytical balance with an approximation to 0.01 g, EC and pH were respectively measured using Conductivity and pH meters, while for SAR measurement total $Ca^{2+}$ and $Mg^{2+}$ were determined by titration and $Na^+$ using of the flame photometer. The SAR expression implicitly assumed that $Ca^{2+}$ and $Mg^{2+}$ had equal selectivity for exchange and calculated with the equation:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

………………………………………………………………… (2)

2.2.2. Plant growth parameters

Observation of plant height and number of leaves was done every 2 weeks during the plant's growth of 2-8 WAT.

2.2.3. Yield parameters

To maintain good fruit size, the fruit from the 1st – 5th clusters of tomato plants were pruned to three fruit per cluster, harvested and collected at 10-14 WAT. The average number and weight of fruits per plant were determined at each harvest until the 5th clusters. Average fresh weight of fruit was weighed using an OHAUS® portable digital scale with an approximation to 0.01 g. The obtained data are reported in kg plant$^{-1}$. The objective of water productivity analysis was to assess plant production (unit of water consumed by tomato plant per kilograms of yield in each polybag). Water productivity (WP) was calculated throughout the total irrigation water applied under each treatment (L plant$^{-1}$) and the proportion of total yield (kg plant$^{-1}$) as shown by [11]:

$$WP \ (L \ kg^{-1}) = \frac{\text{Total irrigation water applied} \ (L \ plant^{-1})}{\text{Yield} \ (kg \ plant^{-1})} \ .................................................... \ (3)$$

2.2.4. Statistical analysis

Analysis of the collected data used SAS package version 9.3 (2012) and the significance of mean values determined by DMRT (Duncan Test) at $P \leq 0.05$. Relationship between SAR and WP of tomato plants were assessed using Pearson correlation analysis.

3. Results

3.1. Characteristic of soil mixed media

Experiment site located in a medium plain dominated by the soil order of Inceptisols [12], pH value of the initial soil mixed media was slightly acidic (Table 1), whereas the high values of organic-C ($C_{org}$) due to the mixture with charcoal husk helped to improve its physical properties. The value of C: N of 16 indicated that the decomposition process of charcoal husk was ongoing. The contents of P, K, Ca and Mg from the initial soil mixed media included in the criteria of marginal range [13] so fertilizer was given as recommended dosage for tomato plants.

3.2. Physicochemical properties of growing media

No interaction was found between NaCl applications and growth stages on the physical properties of growing media. Results of variance analysis showed that concentration of 1000-2000 mg kg$^{-1}$ NaCl at 8 WAT significantly affected EC value, water content and $C_{org}$ of soil mixed media (Table 2). The EC value increased significantly (1.68-2.58 dSm$^{-1}$) due to the application of higher NaCl concentrations. Along with the declined of $C_{org}$ (1.89%), the water content of growing media also significantly
decreased (5.3%) due to the concentration of NaCl 2000 mg kg\(^{-1}\) compared with no application of NaCl, while growth stages of the plant did not affect the physical properties of soil mixed media. The electrical conductivity is less than 1 (dScm\(^{-1}\)) it is a normal soil, 1-2 (dScm\(^{-1}\)) then critical for germination, 2-3 (dScm\(^{-1}\)) critical for growth of salt sensitive crops and greater than 3 (dScm\(^{-1}\)) it is severely injurious to crops [14].

**Table 1. Initial characteristic of soil mixed media**

| Parameters                        | Value |
|-----------------------------------|-------|
| pH (1:H\(_2\)O)                   | 6.2   |
| Water content (%)                 | 8.0   |
| \(\%C_{org}\) (%)                 | 5.3   |
| N (%)                             | 0.2   |
| C/N                               | 26.5  |
| P\(_2\)O\(_5\) (mg kg\(^{-1}\))  | 5.30  |
| K\(_2\)O (mg kg\(^{-1}\))        | 70.4  |
| CEC (cmol\(_c\) kg\(^{-1}\))     | 24.8  |
| Exchangeable K\(^+\) (cmol\(_c\) kg\(^{-1}\)) | 2.1   |
| Exchangeable Na\(^+\) (cmol\(_c\) kg\(^{-1}\)) | 0.2   |
| Exchangeable Ca\(^{2+}\) (cmol\(_c\) kg\(^{-1}\)) | 16.1  |
| Exchangeable Mg\(^{2+}\) (cmol\(_c\) kg\(^{-1}\)) | 3.8   |
| Cl\(^-\) (mg kg\(^{-1}\))        | 16.9  |
| EC (dSm\(^{-1}\))                | 0.98  |
| SAR                               | 0.06  |

\(^{\%C_{org}}\): organic-C; CEC: Cation exchange capacity; EC: Electrical Conductivity

**Table 2. Effects of NaCl concentrations and growth stages on physical properties of soil mixed media at 8 WAT**

| Treatments                      | EC (dSm\(^{-1}\)) | Water content (%) | Organic-C (%) |
|---------------------------------|-------------------|-------------------|---------------|
| NaCl concentration (mg kg\(^{-1}\)) |                   |                   |               |
| \(k_1 = 0\)                     | 1.00\(^a\)        | 27.70\(^c\)      | 5.83\(^b\)    |
| \(k_2 = 500\)                   | 1.01\(^a\)        | 25.10\(^b\)      | 4.82\(^{ab}\) |
| \(k_3 = 1000\)                  | 1.68\(^{ab}\)     | 24.55\(^{ab}\)   | 4.38\(^{ab}\) |
| \(k_4 = 2000\)                  | 2.08\(^b\)        | 22.40\(^a\)      | 3.94\(^a\)    |
| DMRT (0.05)                     | 0.51              | 2.49              | 1.85          |
| Growth stages                   |                   |                   |               |
| \(s_1 = \text{vegetative}\)     | 1.11\(^a\)        | 26.61\(^a\)      | 4.88\(^a\)    |
| \(s_2 = \text{generative}\)    | 1.30\(^a\)        | 26.01\(^a\)      | 4.90\(^a\)    |
| \(s_3 = \text{vegetative + generative}\) | 1.52\(^a\)   | 25.89\(^a\)      | 4.76\(^a\)    |
| DMRT (0.05)                     | 0.28              | 0.84              | 0.19          |

* According to DMRT at \(P \leq 0.05\), mean values with different letters are statistically significant; ns: non-significant; WAT: weeks after transplanting

On the contrary, the interaction of NaCl concentrations and growth stages significantly affected the chemical properties of growing media at 8 WAT (Table 3). The treatments had statistically no
effect on the pH value of soil mixed media, but the increased of NaCl concentrations significantly affected the exchangeable Na⁺, Ca²⁺, Mg²⁺, and K⁺, as well as the level of Cl⁻. Compared to 0 mg kg⁻¹ of NaCl, concentrations of NaCl 1000-2000 mg kg⁻¹ associated with a decrease in the exchangeable Ca²⁺ (0.1-4.1 cmol, kg⁻¹), Mg²⁺ (0.8-1.2 cmol, kg⁻¹) and an increase of exchangeable Na⁺ (1.4-2.0 cmol, kg⁻¹) and Cl⁻ concentration (0.8-11.9 mg kg⁻¹).

Table 3. Effects of NaCl concentrations and growth stages on chemical properties of soil mixed media at 8 WAT

| Treatments | pH (H₂O) | Na⁺ (cmol, kg⁻¹) | Ca²⁺ (cmol, kg⁻¹) | Mg²⁺ (cmol, kg⁻¹) | K⁺ (cmol, kg⁻¹) | Cl⁻ (mg kg⁻¹) | SAR |
|------------|----------|-----------------|------------------|------------------|----------------|---------------|-----|
| k₁s₁       | 6.2      | 0.3 b           | 16.2 a           | 3.9 b            | 2.3 a          | 16.5 a        | 0.09 a |
| k₁s₂       | 6.1 a    | 0.6 a           | 16.3 b           | 3.6 ab           | 2.1 a          | 17.4 a        | 0.19 a |
| k₁s₃       | 6.0 a    | 0.8 a           | 16.0 b           | 3.8 ab           | 1.7 a          | 17.3 a        | 0.25 a |
| k₂s₁       | 6.0 a    | 1.9 a           | 15.1 ab          | 3.0 a            | 1.9 a          | 17.7 a        | 0.63 a |
| k₂s₂       | 6.2 a    | 2.0 a           | 15.6 ab          | 2.8 a            | 1.9 a          | 18.6 a        | 0.66 a |
| k₂s₃       | 6.1 a    | 1.8 a           | 15.7 ab          | 2.6 a            | 1.6 a          | 19.9 a        | 0.60 a |
| k₃s₁       | 6.0 a    | 2.1 a           | 14.1 a           | 2.3 a            | 1.5 a          | 20.1 a        | 0.68 a |
| k₃s₂       | 5.9 b    | 2.2 a           | 13.8 a           | 2.0 a            | 1.3 a          | 20.9 a        | 0.78 a |
| k₃s₃       | 5.9 a    | 2.5 ab          | 13.2 a           | 2.0 a            | 1.6 a          | 23.6 a        | 0.82 a |
| k₄s₁       | 5.8 a    | 2.8 a           | 12.0 a           | 1.8 a            | 1.8 a          | 26.0 ab       | 1.18 a |
| k₄s₂       | 5.7 a    | 3.2 ab          | 12.6 a           | 1.7 a            | 1.9 a          | 26.5 ab       | 1.20 ab |
| k₄s₃       | 5.8 a    | 3.6 b           | 12.8 a           | 2.0 a            | 1.6 a          | 28.8 b        | 1.31 b |
| DMRT       | 5.9      | 1.9             | 2.2              | 1.4              | 1.0            | 12.3          | 1.09  |

* According to DMRT at P≤ 0.05, mean values of interaction between NaCl concentrations x growth stages with different letters are statistically significant; ns: non-significant; SAR: sodium adsorption ratio; k: NaCl concentrations; k₁ = 0 mg kg⁻¹; k₂ = 500 mg kg⁻¹; k₃ = 1000 mg kg⁻¹; k₄ = 2000 mg kg⁻¹; s: growth stages; s₁ = vegetative; s₂ = generative; s₃ = vegetative to generative

3.3. Fruit yield parameters

Results in Table 4 show that neither NaCl concentrations nor growth stages had no influence on the parameters of plant growth (plant height and leaf number) at 2-8 WAT. Data on both parameters show an almost identical trend.

3.4. Fruit yield parameters

The average fruit numbers from the 1ⁿᵗʰ-5ⁿᵗʰ cluster and total yield per plant were not significantly influenced by the treatments. However, highest fruit weight (205.5 g fruit⁻¹) was found in the treatment without NaCl application, while the lowest (153.9 g fruit⁻¹) caused by the NaCl concentration of 1000 mg kg⁻¹ given at 2-4 WAT. During the entire period of plant growth, the amount of total irrigation water applied was not significantly different, but the application of NaCl 500 mg kg⁻¹ at 2-4 WAT caused the highest WP value (36 L⁻¹ kg⁻¹ plant⁻¹). In contrast, the lowest WP value (31.1 L⁻¹ kg⁻¹ plant⁻¹) even produced due to the highest NaCl concentration (2000 mg kg⁻¹) applied at 2-12 WAT.
Table 4. Plant height and leaf number of beef tomato plant due to the application of NaCl concentrations and growth stages at 2-8 WAT

| Treatments NaCl conc. (mg kg⁻¹) | 2 WAT Plant height (cm) | 4 WAT Plant height (cm) | 6 WAT Plant height (cm) | 8 WAT Plant height (cm) | 2 WAT Number of leaves | 4 WAT Number of leaves | 6 WAT Number of leaves | 8 WAT Number of leaves |
|---------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|------------------------|------------------------|------------------------|------------------------|
| k₁ = 0                          | 45.6                     | 7.3                      | 105.2                    | 16.8                     | 158.4                  | 22.4                   | 189.3                  | 30.0                   |
| k₂ = 500                        | 48.6                     | 7.3                      | 109.3                    | 16.1                     | 158.0                  | 20.7                   | 188.0                  | 28.3                   |
| k₃ = 1000                       | 43.4                     | 7.4                      | 101.5                    | 15.2                     | 150.3                  | 20.3                   | 173.7                  | 27.4                   |
| k₄ = 2000                       | 40.0                     | 6.8                      | 101.3                    | 15.1                     | 149.5                  | 19.3                   | 170.4                  | 26.0                   |
| DMRT (0.05)                     | ns                       | ns                       | ns                       | ns                       | ns                     | ns                     | ns                     | ns                     |

Growth stages

| s₁ = vegetative                | 45                       | 7.1                      | 102.4                    | 16.1                     | 155.8                  | 20.9                   | 183.5                  | 28.1                   |
| s₂ = generative                | 44                       | 6.9                      | 105.3                    | 16.1                     | 149.4                  | 20.6                   | 182.0                  | 27.6                   |
| s₃ = veg. + gen.               | 43                       | 6.1                      | 103.3                    | 17.1                     | 152.7                  | 20.4                   | 181.1                  | 27.0                   |
| DMRT (0.05)                     | ns                       | ns                       | ns                       | ns                       | ns                     | ns                     | ns                     | ns                     |

* According to DMRT at P ≤ 0.05, mean values of interaction effect between NaCl concentrations x growth stages with different letters are statistically significant; ns: non-significant; k: NaCl concentrations; k₁ = 0 mg kg⁻¹; k₂ = 500 mg kg⁻¹; k₃ = 1000 mg kg⁻¹; k₄ = 2000 mg kg⁻¹; s: growth stages: s₁ = vegetative; s₂ = generative; s₃ = vegetative to generative; WP = water productivity (g L⁻¹ plant⁻¹)

Table 5. Fruit yield parameters, total irrigation water supply and water productivity of tomato plant due to NaCl applications at different growth stages

| Treatments | Number of fruits plant⁻¹ | Fruit weight (g fruit⁻¹) | Total fruit yield (kg plant⁻¹) | Total irrigation water applied (L plant⁻¹) | WP (L⁻¹ kg⁻¹ plant⁻¹) |
|------------|---------------------------|--------------------------|--------------------------------|---------------------------------------------|----------------------|
| k₁s₁       | 11.0                      | 205.5 b                  | 2.26                           | 63.4                                       | 28.1 a               |
| k₁s₂       | 11.3                      | 202.7 ab                 | 2.29                           | 65.2                                       | 28.5 a               |
| k₁s₃       | 11.8                      | 189.8 a                  | 2.24                           | 63.2                                       | 28.2 a               |
| k₂s₁       | 11.9                      | 155.5 a                  | 1.85                           | 67.1                                       | 36.3 b              |
| k₂s₂       | 12.3                      | 159.3 a                  | 1.96                           | 67.9                                       | 34.6 a               |
| k₂s₃       | 12.5                      | 159.2 a                  | 1.99                           | 67.2                                       | 33.8 a               |
| k₃s₁       | 12.8                      | 153.9 a                  | 1.97                           | 69.5                                       | 35.2 ab             |
| k₃s₂       | 12.6                      | 157.9 a                  | 1.99                           | 68.4                                       | 34.3 a               |
| k₃s₃       | 12.5                      | 164.8 a                  | 2.06                           | 68.7                                       | 33.4 a               |
| k₄s₁       | 12.4                      | 163.7 a                  | 2.03                           | 68.7                                       | 33.8 a               |
| k₄s₂       | 11.9                      | 179.0 a                  | 2.13                           | 68.9                                       | 32.3 a               |
| k₄s₃       | 11.5                      | 190.4 a                  | 2.19                           | 68.0                                       | 31.1 a               |
| DMRT (0.05) | ns                       | 45.6                     | ns                            | ns                                         | 0.78                 |

* According to DMRT at P ≤ 0.05, mean values of interaction effect between NaCl concentrations x growth stages with different letters are statistically significant; ns: non-significant; k: NaCl concentrations; k₁ = 0 mg kg⁻¹; k₂ = 500 mg kg⁻¹; k₃ = 1000 mg kg⁻¹; k₄ = 2000 mg kg⁻¹; s: growth stages: s₁ = vegetative; s₂ = generative; s₃ = vegetative to generative; WP = water productivity (g L⁻¹ plant⁻¹)
4. Discussion
Physicochemical characteristics of soil mix media used in this study were found to be mutually associated with the time, intensity of NaCl applications and growth stages. As expected, the EC values of the growing media at 8 WAT significantly increased (1.00-2.35 dSm⁻¹) due to the application of higher NaCl concentrations. Data in Table 2 indicates that with the time salt buildup in the growing media and the application of various concentrations of NaCl was the cause of decreasing water content compared with no NaCl application.

With time, an increase in NaCl concentrations tended to slightly decrease the pH value of the growing media. This decline was mainly due to the loss of Ca ion and proton transferred by Na⁺ from the salt application. Moreover, through the exchangeable ions, the Na ion resided in the soil particles and releasing other ions such as Ca, Mg, and K into the soil solution (Table 3). [15] stated that changing H⁺ ion concentration made some ions more available to the plant while hindering other ions. A comparable result was reported by [16] that salt influenced the chemistry of growing media in which it infiltrates, so the slightly decreased pH value of growing media was associated with a decreased in the exchangeable Ca²⁺ and Mg²⁺ and an increased in the exchangeable Na⁺. Meanwhile soluble K⁺ in the growing media was not significantly different.

The total salt accumulation in the soil mixed media as measured by EC, varied similar to SAR. The range of SAR value from 0.09 – 1.31 (Table 3) shows that the higher SAR value had a potential for salt accumulation in the growing media, since Ca and Mg had the same selectivity and exchange properties, so the composition of the exchange phase was determined by the total concentration of ions that could be exchanged rather than their activity.

Both treatments had no influence on growth parameters of tomato plants (Table 4), as a result of differences in the rootstock and seedling cultivar used in this study, despite the tolerance or resistance and sensitivity traits of a plant cultivar that will determine crop yield.

The number of fruits and total yield per plant were not significantly affected by the interaction of NaCl concentrations and growth stages. However, the application of NaCl 1000 mg kg⁻¹ at vegetative stage (2-4 WAT) produced the lowest individual fruit weight (153.9 g fruit⁻¹) and the highest (205.5 g fruit⁻¹) resulted in the treatment without NaCl application (Table 5). [17] reported that the decreased of tomatoes fruit weight was one of the causes of declined yields per plant or it could also be triggered by the low amount of fruits produced per plant. Previously, [18] revealed that higher levels of salt concentration had more effect on large-size tomato cultivars than the smaller one so that the difference in fruit size (weight per fruit) could cause the difference on total fruit yield. Apparently, the fruit pruned from clusters 1 - 5 of tomato plants tended to improve the size (weight) of the growing fruit. Fruit harvested gradually from the lower clusters increased the fruit size in the upper cluster. Since the amount of fruit tends to be constant, there was a relationship between number, size, and total fruit yield, so the number and fruit size will adapt to reach the potential of total yield.

Water is depleted when it is consumed by evapotranspiration, is incorporated into a product, and flows according to the ability of the soil to pass a certain water amount until it stops at a certain soil layer. Because the total fruit weight for a productive cycle of plant reflected fruit yield [19] while tomato plants pertained as salt moderately sensitive [20]; [21] thus the WP values referred to total water consumed in relation to crop production [22]. Regardless of the total irrigation water applied during the experiment, highest WP value of tomato plant (36 L⁻¹ kg⁻¹ plant⁻¹, Table 5) was found due to the application of NaCl 500 mg kg⁻¹ at the vegetative stage which posed SAR value of 0.66 (Table 3).

In contrast, the lowest WP value (31.1 L⁻¹ kg⁻¹ plant⁻¹) was produced due to the highest NaCl concentration (2000 mg kg⁻¹) given at vegetative until generative stages (2-12 WAT) which resulted in highest SAR value (1.33) The lowest WP response to higher SAR value in this study could be as a result of the excess soluble salt lowered the osmotic potential energy of soil water in the growing media, thus lowered the water availability (Table 2), as well as the level of Ca, Mg, and K in the soil mixed media (Table 3).

The negative relationships between SAR and WP of tomato plant due to NaCl application at different stages was also reflected in the result of this study (Figures 1a-c). The gradually increasing...
SAR significantly decreased WP value, as shown by the Pearson correlation coefficient ($r$) value ranged from 0.37-0.89.

Figure 1a-c. Relationship between sodium adsorption ratio and water productivity of tomato plant due to NaCl application at 2-4 WAT (a); 5-8 WAT (b) and 2-12 WAT (c)
5. Conclusions
The result of this study clearly pointed out that NaCl applications at different plant growth stages changed physicochemical properties of growing media which led to an increase of Na\(^+\) and Cl\(^-\) concentrations, decreased exchangeable K\(^+\), Ca\(^{2+}\) and Mg\(^{2+}\) in soil solution. Plant growth parameters were not affected by NaCl applications at different growth stages, even without NaCl addition resulted in the highest individual fruit weight. Lower WP value due to NaCl applications at different growth stages indicated the capability of the plant to increase the beneficial use of water supply (uptake - transpiration) against the non-beneficial loses (evaporation).

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