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# Maize Tolerance to Salinity of Irrigation Water

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## ABSTRACT

Crop salt tolerance is generally assessed as the relative yield response to the increasing of root zone salinity. This paper studied the maize tolerance under salinine water (ECw) and their relationship with the changes of soil chemistry characteristics, crop growth and yield of maize. The seven level of water salinity were 0.66, 0.93, 1.57, 1.68, 2.46, 3.35, 3.85 mS $cm^{-1}$ and three local maize from Madura, Pasuruan and Probolinggo were evaluated to soil electric conductivity (ECe), pH, available -N. -P. and -K as well as plant height and seed weight The experiment indicated that saline water (ECw) up to a certain concentration increased soil salinity (ECe) and pH, but decreased nutrient availability, plant height, fresh and dry weight of maizes. ECw level between 1.5 to 1.7 mS $cm^{-1}$ gave the best results compared to others, because of soil nutrients and water availability optimum. Maize of Madura and Pasuruan were more tolerant than Probolinggo giving ECw up to 3. 85 mS $cm^{-1}$, although their maize seed dry weight were lower.

***Keywords***: Crop salt tolerance, EC, maize, pH, seed weight

## INTRODUCTION

Crop salt tolerance is influenced by plants, soil, water and environment. Generally, it has been considered as a response to the relative yield because the increase of soil salinity (ECe) or irrigation water (ECw) in the root zone compared to certain ECe under nonsaline conditions in root zone (Maas and Hoffman 1975). Maize tolerance to salinity was varied between varieties, which were classified as the more sensitive (Katerji *et al.* 2001), sensitive enough (Katerji *et al.* 2004), sensitive (Jumberi 2002), and tolerant (Katerji *et al.* 2000). They have a root system that efficiently limited the transport of $Na^+$ and $Cl^-$ into the stem (Maas and Hoffman 1975; Benes *et al.* 1997).

Salt stress due to high soluble salts in the plant and up to certain levels can damage the plant. Salts cause plant stress, among others were NaCl, $Na_2SO_4$, $CaCl_2$, $MgSO_4$, $MgCl_2$ which dissolve in water. Its influenced on most species depends on the total concentration of salt. If the proportion of the Na, Cl. and B ions excess it can be toxic to specific plants. The high of Na and Ca will inhibit K uptake by plants. The higher NaCl concentration in the soil, the higher the osmotic pressure and soil electrical conductivity. Salt stress induces $Na^+$ and $Cl^-$ accumulation while it decreases $K^+$ and $Ca^{2+}$ levels in shoot and root, increases soil pH and ESP (Exchangeable Sodium Percentage) because of the complex absorption is filled by $Na^+$ ions. Plant growth will be drastically decreased if the ESP reaches 10% (Singh *et al.* 2003). Concentrations of 100 and 430 mM NaCl and Boron, respectively and 20 and 40 mg $kg^{-1}$, respectively did not show symptoms of NaCl and B toxicity for 20 days despite a lot of $Na^+$ accumulated in roots and boron is transpiration to leaves (Bastías *et al.* 2004).

The use of saline water (ECw) caused a higher soil saline (ECe) (Mindari *et al.* 2004; Cooper *et al.* 2006); Ma *et al.* 2008; Pang *et al.* 2010 ). Application of saline water decreased all growth parameters (Khodary 2004; Mansour *et al.* (2005); Kang *et al.* 2010), and it also can hazard plant production (Feng *et al.* 2003; Amer 2010). Higher

NaCl concentration decreased fresh mass (FM), dry mass (DM), and relative growth rate (RGR) of shoots and roots, as well as leaf area ratio (LAR) in two Zea mays cultivars (salt sensitive Trihybrid 321 and salt tolerant Giza 2). Mansour et al. (2005). High evaporation progressively increases the salt strength to hold water in the soil and make it more difficult to attract water, so the water salinity increases (Thomas 2001).

Maize that received drip irrigation with saline water <10.9 dS $m^{-1}$ did not affect the emergence under three years field experiments (Kang *et al.* 2010). However, the seedling biomass decreased and the plant height, fresh and dry weight in the thinning time also decreased by 2% for every 1 vs.-1 increasing in salinity of irrigated water. The decreasing rate of the fresh yield was about 0.4–3.3% NaCl significantly reduced ribulose 1.5-bisphosphate carboxylase (Rubisco) activity, photosynthetic efficiency and pigmentation as well as sugar contents (Khodary 2004). While Maize that was irigated with a salin water of 9 - 3 dS $m^{-1}$ considerably improved grain yield that was 2.33-4.43 Mg $ha^{-1}$ (Guelloubi *et al.* 2003). Irrigation with saline-sodic water with higher levels of salt caused linearly increasing the soil hydraulic characteristics (Bethune and Batey 2007).

The brackish water irrigation with salt content of 3.0–5.0 g $L^{-1}$ significantly increased the salt content at different soil depths in the upper 1 m soil layer during the two growing seasons (Pang *et al.* 2010). Application of fresh water (0.89 dS $m^{-1}$), saline water (4.73 dS $m^{-1}$), or mixing fresh plus saline water (2.81 dS $m^{-1}$) caused significantly increasing soil salt accumulation either by increasing or decreasing of irrigation salinity. Leaf area index, harvest index, and yield were the greatest when fresh and adequate irrigation were applied. Grain yield was correlated significantly ($r^2 \geq 0.95$) by either irrigation or salinity conditions with no interaction (Amer 2010).

High salt concentration in irrigation water reducd the grain and plant dry weight. Maize relative yield was 100% ECe 1.1 and ECw 1.7-1.2 mS $cm^{-1}$, respectively, 90% DHL was about 1.8-1.7 mS $cm^{-1}$, 75% ECw was 2.5 mS $cm^{-1}$ and the yield was down 50% if ECw 3.9 and ECe 5.9 mS $cm^{-1}$ (Grattan 2002). The maximum grain yield variability is on the average 1.41 Mg $ha^{-1}$ and for some specific year the value reaches 2.11 Mg $ha^{-1}$(Bergez and Nolleau 2003).

Salinity reduced phosphate uptake and accumulation as well as plant uptake of K, Na, and Cl. Salinity dominated by Na salts reduced $Ca_2$ availability, $Ca_2$ transport and mobility to the growing regions of the plant, which affected the quality of both vegetative and reproductive organs, plant metabolism, susceptibility to injury or internal nutrient requirement (Grattan and Grieveb 1999).

The purpose of this study was to assess the tolerance of three local maize at the level of water salinity and it effect o soil salinity (ECe), pH, plant uptake of NPK and plant growth and yield.

## MATERIALS AND METHODS

### Experimental Design

A pot experiment was arranged in a Completely Randomized Factorial Design. It was conducted at Faculty of Agriculture, University of Pembangunan Nasional "Veteran" East Java, Surabaya to determine soil electrical conductivity and pH changes, plant -N,-P, -K contents, and yield dry weight under salt water treatment on maize. The first factor was three local maize from Madura (L1), Pasuruan (L2), and Probolinggo (L3), while the second factor was seven levels of saline solution with Electrical Conductivity of 0.66, 0.93, 1.57, 1.68, 2.46, 3:35, and 3.85 mS $cm^{-1}$, respectively. Each treatment combination was repeated three times, so that total was 63 experimental units.

### Study Site and Treatment

Soil samples (order Inceptisol) were taken from Mojokerto at a depth of 0-20 cm, air dried and sieved with a 2 mm sieve. Soil were weighed 5 kg equivalent to absolute dry weight was mixed with 100 g (40 Mg $ha^{-1}$) of organic fertilizer and put into the pot with 5 kg capacity, incubated at field capacity in room temperature for 2 weeks. Organic fertilizer was made from a mixture of animal manures (cow and goat) and leaf compost with a ratio of 1:1. After incubation, the basic NPK fertilizers equivalent to 200 kg $ha^{-1}$ was added. Fertilizer requirements for the 5 kg soil equivalent to 5 × 150 mg = 750 mg $pot^{-1}$. Total fertilizer demand for the 63 pot was 63 × 750 mg = 47,250 mg = 4,725 g.

The first local maize was taken from the Kombangan village, Geger-Bangkalan District, Madura Island. The second local maize was taken from the Blarang village, Pasuruan District, and the third local maize was taken from the Wedusan village, Tiris -Probolinggo district. Four seeds of maize were planted per pot and then a light irrigation water (ECw <1) was applied up to field capacity. After a planting for 2-weeks, the plants were thinned and left 1 plant per pot and its growth was maintained until harvest.

Irrigation water was prepared from a solution containing a mixture of soluble salts that consists of (1) $MgSO_4.7H_2O$, (2) $Na_2SO_4$, (3) $CaCl_2.2H_2O$, (4) $MgCl_2.6H_2O$, and (5) NaCl with a concentration of 0.66 - 3.85 mS $cm^{-1}$. The treatment used were the level of saline water that were E0 (control) = 0.66 mS $cm^{-1}$, E1 = EC 0.93 mS $cm^{-1}$, E2 = EC 1.57 mS $cm^{-1}$, E3 = EC 1.68 mS $cm^{-1}$, E4 = EC 2.46 mS $cm^{-1}$, E5 = EC 3.35 mS $cm^{-1}$, E6 = EC 3.8 mS $cm^{-1}$. Level EC1, EC2, EC3, EC4, EC5, and EC6 were weighed, each for 100, 200, 300, 400, and 500g, respectively, and then dissolved in 1 liter of solution. Saline water (ECw 0 to 3.85 mS $cm^{-1}$) was applied at three weeks after planting (WAP). Plants were maintained in a screenhouse from March until June 2010 with an 10 hour photoperiod, and normally the temperatures were in the ranged of 27-30 ºC. Pest control was carried out if a pest attack symptom was found and a preventive action was performed by a mechanical handling.

Soil pH and EC were measured from the soil paste with a ratio of soil and water = 1: 1. Plant height was measured from the bottom to tip of maize. To measure leaves index, about 0.25 g leaves were weighed oven dried at 60-70°C and grounded to a 20 mesh sieve, then to be wet digested with 4 ml of $H_2SO_4$ dan $H_2O_2$ mixture. Content of $NH_4^+$, $NO_3^-$, $H_2PO_4^+$, and $K^+$ in digest were determined with Spectroquant Pharo 100.

## Statistical Analysis

Data were analyzed by analysis of variance (ANOVA). Means of value were tested by Least Significance Different (LSD) at $P$ = 0.05 to determine the level tolerance of maize using variable ECw and optimum yield.

## RESULTS AND DISCUSSION

## Soil pH and EC

Soil pH and EC values of maize in the growing media that had been given ECw 0.66 - 3.85 mS $cm^{-1}$ were varied among maize that were planted on soil from Madura, Pasuruan and Probolinggo. The increase in soil pH were almost similar among them, but the ECe values were varied depend on maize plants. The values of pH increased 1.1-1.2 times and ECe increased up to 2.03 - 2.6 times. The ECe value in the media of Madura maize were changed from1.58 mS $cm^{-1}$ to 4.12 mS $cm^{-1}$, in the Pasuruan maize was changed from 1.18 mS $cm^{-1}$ to 4.15 mS $cm^{-1}$ and in the Probolinggo maize was change from 0.73 mS $cm^{-1}$ to 3.46 mS $cm^{-1}$ (Tabel 1 and Figure 1 and 2).

Table 1. Soil pH, EC value, and maize seed weight that were applied by salt water.

| Water salinity ($EC_w$) (mS $cm^{-1}$) | Madura | | | Pasuruan | | | Probolinggo | | |
|---|---|---|---|---|---|---|---|---|---|
| | pH | $EC_e$ (mS $cm^{-1}$) | Seed weight (g $plant^{-1}$) | pH | $EC_e$ (mS $cm^{-1}$) | Seed weight (g $plant^{-1}$) | pH | $EC_e$ (mS $cm^{-1}$) | Seed weight (g $plant^{-1}$) |
| 0.66 | 6.98 a | 1.58 a | 7.52 bc | 6.84 a | 1.18 a | 2.66 b | 6.89 a | 0.73 a | 17.48 d |
| 0.93 | 6.95 a | 3.24 b | 7.43 b | 6.91 a | 1.99 b | 2.13 ab | 6.91 a | 1.81 b | 18.89 e |
| 1.57 | 7.21 ab | 3.21 b | 8.54 c | 6.94 a | 3.67 c | 2.44 ab | 7.03 ab | 2.74 c | 19.22 e |
| 1.68 | 7.41 b | 3.39 b | 6.16 a | 7.22 ab | 3.70 c | 3.05 b | 7.26 ab | 3.05 c | 17.49 d |
| 2.46 | 7.47 b | 3.58 b | 8.13 bc | 7.64 b | 3.48 c | 2.66 b | 7.44 b | 3.14 c | 14.01 c |
| 3.35 | 7.47 b | 3.56 b | 9.15 c | 7.71 b | 4.04 c | 1.49 a | 7.76 b | 3.12 c | 11.17 b |
| 3.85 | 7.93 c | 4.12 bc | 9.38 c | 8.01 b | 4.15 c | 2.25 ab | 7.84 b | 3.46 c | 9.75 a |
| $BNT_{0.05}$ | 0.73 | 0.81 | 1.07 | 0.73 | 0.81 | 1.07 | 0.73 | 0.81 | 1.07 |

Table 2. Nutrient uptakes of $NO_3^-$–N. $NH_4^+$–N. $H_2PO_4^+$ and $K^+$ by maize that were applied by salt water

| Water salinity (ECw) (mS cm$^{-1}$) | Nutrient uptake (mg plant$^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $NO_3^-$–N | | | $NH_4^+$–N | | | $H_2PO_4^+$ | | | $K^+$ | | |
| | $L_1$ | $L_2$ | $L_3$ | $L_1$ | $L_2$ | $L_3$ | $L_1$ | $L_2$ | $L_3$ | $L_1$ | $L_2$ | $L_3$ |
| 0.06 | 0.03 ab | 0.11 a | 0.12 c | 0.02 ab | 0.07 a | 0.08 b | 0.06 a | 0.18 a | 0.19 a | 1.64 a | 4.75 b | 3.01 b |
| 0.93 | 0.05 ab | 0.09 a | 0.06 ab | 0.03 b | 0.06 a | 0.04 a | 0.08 a | 0.15 a | 0.10 ab | 1.98 ab | 3.44 ab | 0.73 a |
| 1.57 | 0.03 a | 0.12 a | 0.03 a | 0.02 ab | 0.08 a | 0.03 a | 0.04 ab | 0.19 a | 0.05 ab | 1.30 a | 2.40 a | 2.87 b |
| 1.68 | 0.02 a | 0.11 a | 0.08 b | 0.01 a | 0.07 a | 0.05 ab | 0.03 ab | 0.17 a | 0.12 b | 1.22 a | 2.77 a | 6.63 d |
| 2.46 | 0.03 a | 0.09 a | 0.04 ab | 0.02 ab | 0.06 a | 0.04 a | 0.06 ab | 0.14 a | 0.07 bc | 1.79 ab | 2.31 a | 2.46 b |
| 3.35 | 0.03 a | 0.12 a | 0.10 bc | 0.02 ab | 0.08 a | 0.07 b | 0.05 ab | 0.19 a | 0.16 bc | 1.84 ab | 2.30 a | 4.73 c |
| 3.85 | 0.06 b | 0.20 b | 0.13 c | 0.04 b | 0.12 b | 0.08 b | 0.11 b | 0.30 b | 0.20 c | 3.02 b | 5.18 c | 5.11 c |
| LSD 0.05 | 0.04 | | | 0.02 | | | 0.092 | | | 1.34 | | |

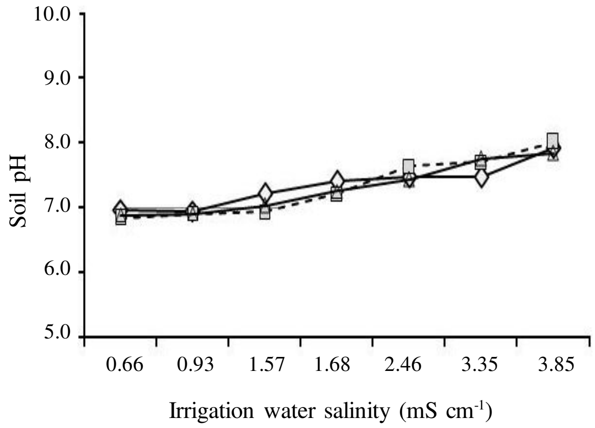


Figure 1. Effect of water salinity on soil pH. —◇— = maize from Madura, - -□- - = Pasuruan, and —△— = Probolinggo, respectively.

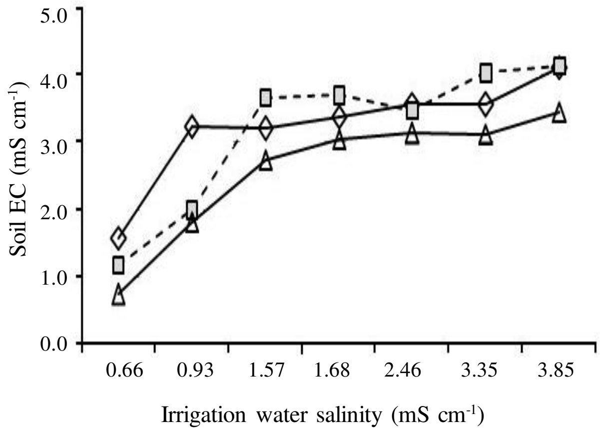


Figure 2. Effect of water salinity on soil salinity (ECe). —◇— = maize from Madura, - -□- - = Pasuruan, and —△— = Probolinggo, respectively.

## Nutrient Uptake

Maize that was treated by saline water until level ECw 3.85 mS cm$^{-1}$ significantly increased $NO_3$-N, $NH_4^+$-N, $H_2PO_4^-$ and $K^+$ plants uptake. $NO_3$-N uptake of maize from Pasuruan was greater than others, and from Madura was the smallest. Nutrient uptake of maize that accepted water salinity of ECw 0.66 mS cm$^{-1}$ was higher than others, while ECw increased (ECw > 0.66 mS cm$^{-1}$) (Table 2). Uptake of $NO_3$-N were higher than $NH_4^+$-N. $NO_3$-N uptakes of local maize from Madura, Pasuruan, and Probolinggo were 0.06, 0.20, and 0.13 mg plant$^{-1}$, respectively and $NH_4^+$-N uptakes of the three maize were 0.04, 0.12 and 0.80 mg plant$^{-1}$, respectively. Uptake of $H_2PO_4$ of maize from Madura, Pasuruan, and Probolinggo reached 0.11. 0.30 and 0.20 mg

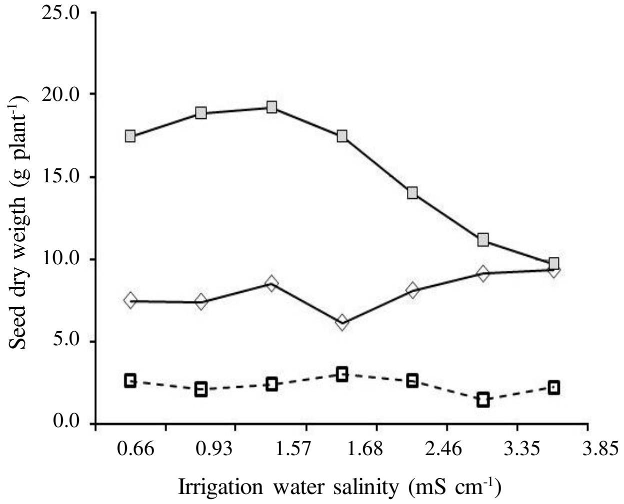


Figure 3. Effect of water salinity on dry weight of maize seed. ——◇—— = maize from Madura, – –□– – = Pasuruan, and ——△—— = Probolinggo, respectively.

plant$^{-1}$, respectively. In addition, $K^+$ uptake of them was 3.02, 5.18. and 5.11 mg plant$^{-1}$, respectively and K uptake were the highest among the other elements. According to Fathan *et al.* (1988) minimum uptake of nutrients in the maize crop was N = 1.41, $H_2PO_4^-$ = 0.16 and $K^+$ = 2.00 mg plant$^{-1}$, in the other hand, according to Nuryamsi *et al.* (2008) absorption of each elements above could reach 381.09, 27.74, and 92.59 mg plant$^{-1}$, respectively. Table 2 shows the N and P uptakes were at below minimum value of nutrient uptake in maize crops, but K uptake was upper minimum value.

All maizes that were applied by ECw level about 1.57 mS cm$^{-1}$ increased seed dry weight, but the last decreased with increasing of level ECw until 3.85 mS cm$^{-1}$. Dry weight of maize seed from Probolinggo decreased dramatically, while the local maize of Madura and Pasuruan slightly increased or even stable although the final results were less than Probolinggo (Table 2 and Figure 3). The same yields were obtained by Bergez and Nolleau 2003); Mansour *et al.* (2005); Guelloubi *et al.* (2010); and Pang *et al.* (2010). The height of maize from Madura was lower than fom Pasuruan and Probolinggo, with a maximum height were 153 cm, 214 cm and 218 cm, respectively.

## Discussion

The increasing ECe values in planting media of local maize from Madura, Pasuruan, and Probolinggo varied between 1.15 to 2.63 times which were caused by differences in the ability of plants to adaptation the extracted salt solution in soil. Madura and Pasuruan maize absorbed and transpirated more water so that many salts were left in the soil media which resulted high in soil pH and EC. The opposite was occurred in Probolinggo maize. These were appropriate according to Cooper *et al.* (2006) and Pang *et al.* (2010), who explained that applying water that containing a chemical salt (ECw) could increase the ECe with a ratio of 1:1. The increasing of soil pH resulted the higher of $NO_3^-$ uptake than $NH_4^+$ so that hidrolysis of $NH_4^+$ salts increased soil pH. The increasing of soil pH and EC was because of the hydrolysis of Ca-, Mg-, and Na-carbonate and chloride salts from the highest salts that were applicated until ECw 3.8 mS cm$^{-1}$, thereby increasing the levels of soil hydroxyl.

The results showed that the uptake of $NO_3^-$-N was greater than the $NH_4^+$-N. These were appropriate according to Fageria (2009), where aerobe soil media caused $NO_3^-$ concentration was more dominant than soil $NH_4^+$, or $NH_4^+$ was adsorbed in a complex of soil colloid, so diffuse mobile of $NH_4^+$ was little than $NO_3^-$. Nitrogen was served to increase plant height and protein content and to give a green color on the leaves and nucleic acids (DNA and RNA) (Mc Cauley *et al.* 2009; Fageria 2009). Therefore, if these elements was lucking, it will make the lower leaves chlorosis, stunted, and its growth was more slowly than the older leaves. The N uptakes of Madura Local maize were slightly than others, it caused stunted growth and grain yield was also smallest. N uptakes of maize from Pasuruan were not significantly different at all treatments so it was difficult to evaluate the crop tolerance. $NO_3^-$-N uptake of maize from Probolinggo was more higher if the salinity was low and it declined if the salinity increased. These were in agreement with Huber and Thompson (2007), where the presence of chloride ($Cl^-$) ion reduced $NO_3^-$ uptake and insured $NH_4^+$ uptake.

Availability of $H_2PO_4^-$ in soil is affected by pH values. At high soil pH (alkaline), the soil contains a lot of calcium, especially calcium carbonate, so that the available P will be fixed by ions $Ca^{2+}$, and it becomes unavailable to plants (Nautiyal *et al.* 2006; Mc Cauley *et al.* 2009). The solubility of phosphate was influenced by the pH medium, if the final pH of the medium was about 8.0 or above, P significantly deccreased. Calcium played a role in phosphate solubility which were determined by its sources, where the $CaCl_2$ and $CaSO_4$ would improve P solubility, while the $CaCO_3$ and $CaOH_2$ at concentrations 2.5 and

5.0 mg $ml^{-1}$ would be lowering P solubility and it made the soil pH to be alkaline. $H_2PO_4^-$ uptake of maize from Madura, Pasuruan, and Probolinggo reached 0.11, 0.30, and 12.20 mg $plant^{-1}$, respectively. The ability of $H_2PO_4^-$ ion uptake by maize from Madura was lower than others, therefore the plant growth was also low. Lack of $H_2PO_4^-$ uptake would impact on the lack of energy transfer as a constituent of ATP (adenosine triphosphate), adenosin difosfat (ADP) building blocks of protein, coenzymes, nucleic acids (RNA and DNA), phospholipids membrane and substrate metabolism (Schachtman *et al.* 1998; Mc Cauley *et al*. 2009; Fageria 2009).

Symptoms of P deficiency can be detected in young plants, it may occur at the top or the edges, and it occurs in subsoil's of high calcium carbonate ($CaCO_3$). Plants growing in soil with high $CaCO_3$ are likely to be deficiency of P due to precipitation of Ca-P minerals (Mc Cauley *et al.* 2009). The low uptake of P causes the filling seeds on the cob is also disrupted thus it has negative impacts crop yield of maize. The forms of available P in solution are changed with pH. If the pH is higher, then most P are in the form of $HPO_4^{2-}$, whereas $H_2PO_4^-$ is only in small amounts. At the high soil pH, decreasing in available P in associated with Ca ions which are expressed by the equation:

$Ca(H_2PO_4)_2$ (P-soluble) + $2Ca^{2+}$ $Ca_3(PO_4)_2$ (P insoluble) + $4H^+$

$K^+$ uptake of maize from Madura was lower (3.02 mg $plant^{-1}$ ) than others (Pasuruan and Probolinggo: 5.18 and 5.11 mg $plant^{-1}$, respectively), in the application of water salinity with ECw 3.8 mS $cm^{-1}$. $K^+$ uptake decreased in ECw 1.57 mS $cm^{-1}$ and increased on ECw 1.68 mS $cm^{-1}$ and it was diagnosed due to the high concentration of K in soil solution. The same conditions were found in Probolinggo maize. The opposite of that occurred in Maize of Pasuruan, where the K uptake was highest and it increased in line. At ECw 3.8 mS $cm^{-1}$, K uptake decreased, presumably due to competition between K absorption and other salts. These were appropriate according to the opinion of Majeed *et al.* (2010) and Hadi *et al.* (2007), in which the excess of Na and Cl inhibited plants K uptake. Potassium elements have a function as activators of enzymes in the process of photosynthesis and respiration, translocation of carbohydrates, protein and starchs synthesis, osmoregulation in the stomata open - closed, the stabilization of pH, and membrane transport processes (Schachtman *et al.* 1998; Grattan and Grieveb 1999; Fageria 2009; Collado *et al*. 2010). If the potassium uptake was low, such as Madura maize, then all these processes were also disrupted, water stress increased, the speed of photosynthesis decreased, so the growth and yield quality was also low. Reduction of $NO_3$-N, $NH_4^+$-N, $H_2PO_4^+$, and $K^+$ uptakes were due to high ECe, it caused salts accumulated in the roots and it covered the entrance of nutrients absorbed by plants. Besides the increasing of salinity, increasing soil pH values also allowed some nutrients to become unavailable to plants.

The different of maize yield productions in various salinity levels were influenced by genetic characteristics and salt concentrations in soil. Probolinggo maize was capable to provide the optimum yields in ECw approximately 1.57 mS $cm^{-1}$ and it decreased drastically if ECw higher or lower. Genetic characteristic of Madura and Pasuruan maize were still capable to survive on ECw rather high (1.7 mS $cm^{-1}$) although the results were lower. This provided that the giving irrigation water with low ECw also did not guarantee to have in better growth, because the availability of nutrients N, P, and K were also low so it was not sufficient for the plant growth. The high of ECw also did not guarantee the best growth, because the salt content might also inhibit the availability of other nutrients. Madura maize had the lowest uptake of nutrients and water resulted in cell division and nutrient transport were disrupted and plant growth was also impaired. The high concentration of salt in water solution will reduce the plants uptake of $NO_3^-$, $NH_4^+$, and $H_2PO_4$, causing the formation of proteins, sugars, and carbohydrates were compromised. Consequently seed filling on the cobs were also disrupted. The results were consistent with Schachtman *et al.* (1998) where the high salinity in irrigation water could reduce the grain yield and plant dry weight, although it was not extreme.

A crop salt tolerance level was depended on the ability of $Na^+$ and $Cl^-$ transportation to leaves, cell and citoplasmic formed, and salt toxicity (Munn 2002). Collado *et al.* (2010) found that application of NaCl 150 m*M* (EC 13 mS $cm^{-1}$) caused in equilibrium of ionic, membrane permeability changes, and it had a positive correlation with $Na^+$ and a negative correlation with $K^+$. The increasing of salt concentration 200 m*M* ( EC 18 mS $cm^{-1}$ ) was happened as long as 27 planting days, $Na^+$ only had a little accumulation and it had more $K^+$ in tolerant plant , so that K/Na ratio was more higher because of the higher $K^+$ ion total uptake and transport than $Na^+$ (Kaddour *et al.* 2011 and

Grattan 2002). Application of NaCl 150 m*M* (EC 13 mS $cm^{-1}$) caused Na toxicity to plant and plant production was under 50%. Only tolerant plant can defense on salinity. The results of the experiment showed that application of water salinity with ECw 0.66 and 3.58 caused maize seed yield of Probolinggo decreased from 17.48 to 9.75 g $plant^{-1}$ (45%).

## CONCLUSIONS

The sequence of the maize tolernace to salinity from high to low were maize of Madura> Pasuruan > Probolinggo. Provision of saline water (ECw) could increase and decrease ECe and NPK uptake, and maize yield. It suggested that further research to establish the EC of irrigation water and the optimum dose of NPK was needed.

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## REFERENCES

Amer KH. 2010. Maize crop response under managing different irrigation and salinity levels. *Agric Water Manage* 97 (10): 1553-1563. doi: 10.1016/ j.agwat.2010.05.010.

Bastías EI, MB González-Moro and C González-Muru. 2004. *Zea mays* L. amylacea from the Lluta Valley (Arica-Chile) tolerates salinity stress when high levels of boron are available. *Plant Soil* 267: 73-84. doi: 10.1007/s11104-005-4292-y.

Benes SE, R Aragüés, SR Grattan and RB Austin. 1997. Foliar and root absorption of Na+ and Cl" in maize and barley: Implications for salt tolerance screening and the use of saline sprinkler irrigation. *Plant Soil* 180: 75-86. doi: 10.1007/BF00015413.

Bergez JE and S Nolleau. 2003. Maize grain yield variability between irrigation stands: a theoretical study. *Agric Water Manage* 60 (1): 43-57. doi: 10.1016/S0378-3774(02)00152-X.

Bethune MG and TJ Batey. 2007. Impact on soil hydraulic properties resulting from irrigating saline–sodic soils with low salinity water. *Aust J Exp Agric* 47 (3): 273-279.

Collado MB, MJ Arturi, MB Aulicino and MC Molina. 2010. Identification of salt tolerance in seedling of maize (*Zea mays* L.) with the cell membrane stability trait. *Int Res J Plant Sci* 1 (5) : 126-132.

Cooper CA, G Cardon and J Davis. 2006. Salt Chemistry Effects on Salinity Assessment in The Arkansas River Basin, Colorado. Colorado Water Resources Research Institute. Completion Report. No. 206. 50 p.

Fageria NK. 2009. The Use of Nutrient in Crop Plants. CRC Press, pp: 31-159.

Feng GL, A Meiri and J Letey. 2003. Evaluation of a model for irrigation management under saline conditions: I. Effects on Plant Growth. *Soil Sci Soc Am J* 67 (1): 71-76. doi: 10.2136/sssaj2003.7100.

Grattan SR. 2002. Irrigation Water Salinity crop Production. University of California. Agriculture and Natural Resources. 9p

Grattan SR and CM Grieveb. 1999. Salinity mineral nutrient relations in horticultural crops. *Sci Hortic* 78: 127-157.

Guelloubi R, A Hamdy and V Sardo. 2003. Maize Production Under Two Water Saving Techniques: 77-91. http://ressources.ciheam.org/om/pdf/b53/ 00800753.pdf. accessed on 20 September 2010.

Hadi MR, R Khavarinejad and NA Ghoshkolgh-Sima. 2007. NaCl effects on accumulation on minerals (Na, K, Cl) and proline in *Triticum tugidum* L. *Asian J Plant Sci* 6 (2): 379-383. doi: 10.3923/ajps.2007.379.383.

Huber DM and IA Thompson. 2007. Nitrogen and plant disease. In: LE Datnoff, WH Elmer and D M Huber (eds). *Mineral Nutrition and Plant Disease*. St. Paul, The American Phytopathological Society, pp. 31-44.

Jumberi A, M Oka and H Fujiyama. 2002. Response of vegetable crops to salinity and sodicity in relation to ionic balance and ability to absorb microelements. *Soil Sci Plant Nutr* 48: 203-209.

Kaddour R, N Sellami, H Chennaoui, N Nasri, O Baatour, H Mahmoudi , I Tarchoun , M Lachaâl, M Gruber and N Trifi. 2011. Correlation between salt tolerance and genetic diversity between *Sulla carnosa* and *Sulla coronaria*. *Afr J Biotech* 10 (65): 14355-14365.

Kang Y, M Chen and S Wan. 2010. Effects of drip irrigation with saline water on waxy maize (*Zea mays* L. var. ceratina Kulesh) in North China Plain. *Agric Water Manage* 97: 1303-1309. doi:10.1016/ j.agwat.2010.03.006.

Katerji N, JW van Hoorn, A Hamdy and M Mastrorilli. 2000. Salt tolerance classification of crops according to soil salinity and to water stress day index. *Agric Water Manage* 43 (1): 99-109.

Katerji N, JW van Hoorn, A Hamdy and M Mastrorilli. 2001. Salt tolerance of crops according to three classification methods and examination of some hypothesis about salt tolerance. *Agric Water Manage* 47: 149-159.

Katerji N, JW van Hoorn, A Hamdy and M Mastrorilli. 2004 . Comparison of maize yield response to plant water stress caused by salinity and by drought. *Agric Water Manage* 65 (2): 95-101.

Katerji N, JW Van Hoorn, A Hamdy and M Mastrorilli. 2003. Salinity effect on crop development and yield: Analysis of salt tolerance according to several classification methods. *Agric Water Manage* 62 (1): 125-146.

Khodary SEA. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plants. *Inter J Agric Biol* 6 (1): 5-8.

Ma W, Z Mao, Z Yu and MEF van Mensvoort and PM Driessen. 2008. Effects of saline water irrigation on soil salinity and yield of winter wheat–maize in North China Plain. *Irrig Drain Syst* 22: 3-18. doi: 10.1007/s10795-007-9027-1.

Maas E, V and GJ Hoffman. 1975. Crop Salt Tolerance - Current Assessment. U.S. Salinity Laboratory. Agricultural Research Service. U. S. Department of Agriculture. P.0 Box 672. Riverside. California 92502. 42 p.

Majeed A, MF Nisar and K Hussain. 2010. Effect of saline culture on the concentration of $Na^+$, $K^+$ and ClG in *Agrostis tolonifera. Cur Res J Biol Sci* 2 (1): 76-82.

Mansour MMF, KHA Salama, FZM Ali and AFA Hadid. 2005. Cell and plant responses to NaCl in *Zea mays* L. Cultivars differing in salt tolerance. *Gen Appl Plant Physiol* 31 (1-2): 9-41.

Mc Cauley A, C Jones and J Jacobsen. 2009. Plant Nutrient Functions and Deficiency and Toxicity Symptoms. Montana State University, Extension. 16p.

Mindari W, Syekhfani and Z Kusuma. 2004. Reklamasi lahan salin pantai untuk tanaman kacang panjang dan lombok. [Master Thesis]. Pengelolaan Tanah dan Air, Brawijaya University-Malang (in Indonesian).

Munn R. 2002. Comparative physiology of salt and water stress. *Plant Cell Environ* 25: 239-250.

Nautiyal CS, S Bhadauria, P Kumar, H Lal, R Mondal and D Verma. 2000. Stress induced phosphate solubilization in bacteria isolated from alkaline soils. *FEMS Microbiol Lett* 182: 291-296.

Nursyamsi D, K Idris, S Sabiham, DA Rachim and A Sofyan. 2008. Pengaruh asam oksalat, $Na^+$, $NH4^+$. dan $Fe3^+$ terhadap ketersediaan K tanah, serapan N, P, dan K tanaman serta produksi jagung pada tanah-tanah yang didominasi Smektit. *J Tanah Iklim* 28: 69-82 (in Indonesian).

Pang HC, YY Li, JS Yang and YS Liang. 2010. Effect of brackish water irrigation and straw mulching on soil salinity and crop yields under monsoonal climatic conditions. *Agric Water Manage* 97 (12): 1971-1977.

Schachtman DP, RJ Reid and SM Ayling. 1998. Phosphorus uptake by plants: from soil to cell. *Plant Physiol* 116: 447-453.

Singh B, IOA Odeh and AB McBratney. 2003. Acid buffering capacity and potential acidification of cotton soils in northern New South Wales. *Aust J Soil Res* 41(5): 875-888. doi:10.1071/SR02036

Steppuhn H, M Th van Genuchten and CM Grieve . 2005. Root-Zone Salinity: I. Selecting a Product-Yield Index and Response Function for Crop Tolerance. *Crop Sci* 45 (1): 209-220.

Thomas JG. 2001. Irigation Water Quality Guidelines for Mississippi. Mississippi State University.