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Dynamic of Saline Soil Cations after NaCl Application on Rice Growth and Yields

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ABSTRACT

Saline soil cation dynamic is determined by the proportion of salt cations dissolved either acidic or alkaline. Common base cations in saline soil are in the proportion of Na > Ca > Mg > K. They affects the availability of water, nutrients, and plant growth. The six level of NaCl were 0, 15, 30, 45, 60, and 75 mM and two types of soil (saline and non saline) from Gununganyar and Mojokerto were evaluated to soil sample cations taken from depth of 0-5, 5-10, 10-15, and 15-20 cm. Rice growth and yields were measured. The experiment indicated that increasing doses of NaCl increased the soil Na after rice harvest and decreased K, Ca and Mg contents, both of non-saline and saline soil, decreased of rice growth and yield (straw, grain, number of tiller). NaCl up to 30 m*M* caused highest Ca:Mg ratio, about 8, suppressed nutrient available, inhibited root growth and reduced nutrient uptake.

***Keywords*:** Cation dynamic, NaCl, rice yield , saline soil

INTRODUCTION

Saline soil cation dynamics is are determined by the proportion of dissolved cations either acidic or alkaline. Base cations which are common in non-saline soil are Ca, Mg, Na and K in the proportion of Ca> Mg> K> Na. This condition will be turned around when they are in salt affected soils, which are dominated by the Na sorption than Ca, Mg and K (Carmona *et al*. 2010). Ideal cation counterpart for plant growth is Ca:Mg ratio (3-4), K:Mg ratio (<1.5), K:CEC 2% and SAR are depend on ECw, pH (around 6.5), EC 2 (mS cm^{-1}) (Landon 1984). Plants that have high K/Na ratio value gives the best results (Akram *et al*. 2010).

Cations activity is also used to calculate the equilibrium exchange of Ca, Mg, Na, and K with a method that allows the addition of a number of exchanged cations. The value predicted by the three options for EC, SAR and concentration of Ca, Mg, Na, Al, Cl, SO_4, and $HClO_4$, were compared to experimental data obtained from lysimeter studies. Climate change causes changes in soil cation balance as a result of precipitation and evaporation. Precipitation of dissolved salts, mineral weathering and salt reserves to redistribute to the accumulation of salts to the surface and groundwater. Sodium salt dominates some saline soil in the world, but the other salts cations such as calcium (Ca), magnesium (Mg), potassium (K), and ferum (Fe) are also available at a specific location (Rengasamy 2006), are not uniform due to inundation of salt in the soil profile. Dynamic balance of water and salt shows that the soil profile has two zones that are relatively independent of each other, one is a horizon experiences continuous process of alkalization and salinization, while the other horizon is not. When floods, Horizon A_1, B_1 and B_{21}, often become saturated with water, but unsaturated permanently on-B_{22} horizon, with electrical conductivity (ECw) increases suddenly and the peak in EC_w is 45.00 dS m^{-1}, leading to salinization right in horizon, perhaps through episodic salt diffusion and convection. However, washing the salt will affect the concentration in the upper horizon.

Several factors may affect the dynamics of the cation are the texture, cation exchange capacity (CEC), soil porosity and depth of an impermeable layer. The main effect of salinity is reduction of leaf growth that is a direct result in reduced photosynthesis of plants, crop yield, and in the worst conditions can cause crop failure (Shani and Dudley 2001; da Silva *et al*. 2011). Variations in physic-chemical characteristics are shown by changes in pH, EC, dissolved ions, cations exchanged, ESP, SAR, lime, and soil organic matter. In exchange homovalens (K^+ and Na^+) and heterovalen (K^+ and Ca^{++}), the value of K^+ increased with increasing organic matter. Surface charge density increased with increasing CEC and resulted in increased sorption K^+ (Nassem and Bhatti 2000). The accumulation of Na and Cl in the protoplasm caused changes in cell metabolism, inhibited enzyme activity resulted in partial dehydration of the cell, and loss of cell turgor due to reduce water potential in the cell. Excess extracellular Na and Cl also influences nitrogen assimilation, directly inhibits the absorption of N-NO_3 (Yuniati 2004). Exchange reactions can decrease the mobility of ions in the order K> Ca> Mg, which follows the order of increasing ionic radius of hydrated salt 7 sandy soil with low organic matter content (OM), and rich in quartz and halite, (Gacitua *et al.* 2008).

Ca-exchange is in equilibrium with the soil solution. Soluble Ca replenish lost by plant uptake or leaching. Leaching can be significant, on coarse-textured soils where acidic water moving through a lot of profiles. Ca in the soil to form gypsum ($CaSO_4$), secondary deposits or bound with (CO_3^{-2}) and bicarbonate (HCO_3^-), forming calcium carbonate ($CaCO_3$), as a buffer at high pH soil. Because of the strong divalent charge, Ca acts as the 'glue' ion, pulling and shaping clay particles aggregation through a flocculation process (Bohn *et al.* 2001). Availability Mg for plants small as Mg minerals are relatively resistant to changes such as biotite, horneblende, olivene, dolomite, and most of the clay mineral 02:01. Soluble Mg can also precipitate from solution as $MgCO_3$ or $MgSO_4$, often along with $CaCO_3$ in the sub-surface soil. Although Ca and Mg share the same exchange process, Mg adsorbed by soil colloids are less powerful and therefore more susceptible to leaching, especially in sandy soil. Mg^{+2} compete with Ca^{+2}, K^+, and NH_4^+ for plant uptake and cation exchange places. Mg deficiency occurs when other cations dominate the soil, with a low Mg concentrations (<10% base saturation) (Bohn *et al.* 2001 and Korb *et al.* 2005). High Mg-exchange is sometimes associated with low soil permeability and crust and high soil pH, similar to the characteristic of sodic soil, where Na^{+1} and Mg^{2+} dominate. Na monovalent ions (Na^+) dominate the clay surface, resulting in poor soil structure, low soil permeability and bad inherited soil structure (Bohn *et al.* 2001: Rengasamy 2006). Na ions have weakly positive charge is not strong enough to neutralize the negative charge clay particles, causing repel each other, resulting in a soil without gel structure, bad aeration, slow permeability, and low water holding capacity for plant growth. The vegetative growth of rice crops establish after the tsunami but grain formation has been severely affected causing up to 50% yield loss. The lack of grain formation on rice is related to high soil salinity that causes osmotic stress and nutritional imbalance. Ratio of Ca/Mg < 5 and K/Ca+Mg < 0.04 may have cause low P and K availability for plant uptake (Rachman *et al.* 2008).

Na-exchanged can be moved out of the root zone through cation exchange, washing, or cation balance settings that is available for plants (Slaton *et al.* 2004) that the uptake of K, Ca and Mg in irrigated rice are better. Rice planting can be a real alternative to decrease soil salinity, providing good water quality for plants, although the sensitivity to high soil salinity as seed filling phase (Zeng and Shannon 2000; Rachman *et al.* 2008). Although the character of the soil determines the intensity change of the solution, but the influence of plant nutrient uptake processes or rhizosphere modification, primarily by the flow of oxygen in the parenchyma and the deposition of Fe^{3+} in the roots (da Silva *et al.* 2011). This study aimed to examine the dynamics of soil cations after application of NaCl on cation concentration at a depth of 0-20 cm, and its correlations with the growth and yield of rice. If the ratio between the cations are above or below the ideal proportions, Ca: Mg <3 and K:Mg = 1/2, lower crop production. It will be used as a reference saline soil improvement in the next planting practices.

MATERIALS AND METHODS

Study Site and Treatment

Greenhouse experiments were conducted at the Faculty of Agriculture UPN "Veteran East Java on April 2012 until July 2012. Study the dynamics of soil salt cations were done in a pot because of the difficulty to detect activity in the field on flat land. This study refers to previous research conducted by Carmona *et al.* (2010) in the field at different salinity levels (ESP from 5.6 to 32.7%) and the stratified layer of 0-40 cm. He learned to evaluate the dynamics of basic cations in the Albaqualf soil solution with different salinity levels of irrigation to grow rice. Plant stands, dry matter, Na, K and Ca + Mg absorption at full flowering and grain yield, rate of Na, K, Ca and Mg soil, electrical conductivity (EC) were measured every week for observing a drop of ions from the lower layers due to the root influence.

In this study, we worked on the soil saline cations dynamic in the pot scale with the soil depth of 0-20 cm: (1) saline soil samples were taken from Gunuganyar and (2) non saline soil, Inceptisol, was used for comparison which were taken from Mojokerto. First, surface soil was cleaned from animals residues, subsequently soil was to a excavated depth of 20 cm. Disturbed soil samples were put in sacks, tied and were brought to the laboratory and Screenhouse. Both soil samples were air-dried and sieved with a 2 mm sieve. The soil samples were weighed 25 kg equivalent of absolute dry weight at 105^oC temperature, mixed with 120 g (50 Mg ha^{-1}) of organic fertilizer which was made from a mixture of manure and compost leaves in a 1:1 ratio. The soils were put in a bucket with a capacity of 30 kg, and incubated at saturated conditions at room temperature for 2 weeks. After incubation, the basic NPK fertilizer 15-15-15 equivalent to 200 kg ha^{-1} was added. Fertilizer requirements for 25 kg of soil equivalent to $(25/2.10^6) \times$ 200 kg = 2.5 g pot^{-1}. This fertilizer contained 15/100 x 2,500= 375 mg Nitrogren, 375 mg P_2O_5 and 375 mg K_2O.

Inceptisol soil sample from Mojokerto had the following characteristics: pH 6.5, C-organic content 23%, total N 0.14%, C/N ratio of 9, exchangeable ions of -K, -Na, -Ca, and -Mg were 2.54, 1.96, 13.86, and 4.50 cmol kg^{-1}, respectively, CEC 22.54 cmol kg^{-1}, and EC 0.25 mS cm^{-1}, and sandy loamy texture class. Saline soil sample from Gununganyar had the following characteristics : pH 7.3, c-organic content 9%, total N 0.74%, ratio C/N of 12, exchangeable of -K, -Na, -Ca, and -Mg respectively 2.31, 2.46, 17.57, and 1.40 cmol kg^{-1}, CEC 48.12 cmol.kg^{-1}, EC 1.15 mS cm^{-1}, and clay texture class.

The Ciherang variety rice was used as an indicator of growth, because these varieties were often planted by farmers in site location (Gununganyar, Sidoarjo), and it had midle tolerant variety to saline soil. Rice seedling in by immersion in a 5% salt solution. Seeds were planted to a sink and were taken to a nursery. Two seeds of rice were planted per pot and then a light irrigation water (ECw <1) was applied up to saturate. After a planting for 2-weeks, the plants were thinned and left 1 plant per pot and its growth was maintained until harvest.

Experimental Design

A pot experiment was arranged in a Completely Randomized Factorial Design. It was conducted at Faculty of Agriculture, University of Pembangunan National "Veteran" East Java, Surabaya. Parameters were soil cation dynamics, soil electrical conductivity and pH changes, rice plant - N,-P, -K –Ca, Mg, Na contents, and yield dry weight under NaCl treatment. The first factor was two soil type, non saline soil from Mojokerto (T1) and saline soil from Gununganyar (T2), while the second factor was six levels of NaCl powder of 0, 15, 30, 45, 60, and 75 m*M*, respectively. Each treatment combination was repeated four times, so that total was 48 experimental units. The six level of NaCl were Na_0 (control) = 0.00 m*M* NaCl, Na_1 =15 m*M* NaCl, Na_2 = 30 m*M* NaCl, Na_3 = 45 m*M* NaCl, Na_4 = 60 m*M* NaCl, and Na_5 = 75 m*M* NaCl. Each of them was equivalent to 0, 877.5, 1755.0, 2632.5, 3510 and 4387.5 mg NaCL. Water with EC <1 mS cm^{-1} was added to soil until saturated. Soil EC were 0, 1.37, 2.74, 4.11, 5.48 and 6.85 mS cm^{-1}, respectively, after 3 weeks seedlings. Plants were maintained in a screen house from April until July 2012 with an normally temperatures which 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.

Sampling and Asessment

Soil cations were measured from a catch soil solution (50 ml) in a bottle that was connected with a hose attached to a depth of 0-5, 5-10, 10-15, 15-20 cm in edge of pot before and after NaCl treatment. Soil solution was filtered before analyzing cation content. The Ca and Mg analysis were done by burning the sample to eliminate the interference of organic matter, then it was titrated with 1.0 *N* EDTA. While K and Na contents were measured with Flamefotometer. Amount of soluble cations were evaluated against 5 cm depth interval from the surface and it was correlated to the growth and yield of rice. Soil pH and EC were measured in the soil paste with a ratio of soil and water = 1:1 after harvesting. Soil exchangeable bases were measured by extracting the soil with 1.0 *N* ammonium acetate solution with a ratio of soil and solution = 1:10, which was followed by measuring the content of Ca- and Mg-exchangeable by EDTA titration and Na- and K- exchangeable by Flamefotometer. To measure rice grain cations, about 0.25 g grains were weighed, oven dried at 60-70^o C and grounded to a 20 mesh sieve, then to be wet digested with 4 ml of H_2SO_4 and $HClO_4$ mixture. Dry weights of root, hay, grain, panicle were measured by oven at a temperature of 70 ^oC. Crop production index was calculated by dividing grain weight by the number of heavy grain straw, panicle, and roots. The value obtained was correlated to the growth and production parameters and soil physical-chemical characteristics after NaCl treatment. The values obtained were correlated with growth parameters and production as well as soil physical-chemical properties after administration of NaCl. The highest correlation between parameter values were the best cations balance. Content of NH_4, Ca, Mg, Na, and K^+ $H_2PO_4^+$, in digest were determined with titration, flamephotometer, and spectrophotometer, respectively.

The Corrected Cation Dynamics

The obtained data of soil solution cation was corrected with soil depth, soil pH, clay, sand, and silt content. In order to obtain the correlation between soil cation content using ratio of Ca/Mg, K/Mg, and K/Na Growth and crop production, we measured root weight, the content of bases in plant tissues, as well as crop production index, and the weight ratio of seed weight plant organs. The resulting value was correlated with the growth and production parameters and physical-chemical characteristics of soil in order to assess the balance of cations that gave the best result. Allegedly with increasing salinity would reduce the proportion of Na/ "(Ca+ Mg)/2 Sodium Absorption Ratio (SAR), or K: Na and K: Mg that affected plant growth and production. Data measurements of Na, Ca, and Mg as well as CEC were used to calculate SAR and ESP.

Statistical Analysis

Data were analyzed by analysis of variance (ANOVA) using Microsoft Excel. Means of value were tested by Least Significance Different (LS D) at $P = 0.05$ to determine the soil type and the level effect to rice using variable of NaCl and optimum yield.

RESULTS AND DISCUSSION

Bases Content

Soil potassium content in non-saline soil were lower than saline soil, respectively between 1.51 - 10.21 and 1.84-37.42 mg kg^{-1} (Table 1). Soil sodium (Na) content in both soil samples were almost similar in the range between 36.48-36.63 mg kg^{-1} for non-saline and saline soil between 36.59-36-63 mg kg^{-1} for saline soil. Soil calcium (Ca) content was the highest among other soil cations between 88-147 mg kg^{-1} for non-saline soil and 88-118 mg kg^{-1} for saline soils. The content of magnesium (Mg) of soil was ranged from 28.20 to 49.20 mg kg^{-1} for non-saline soil and between 29.10 mg kg^{-1} to 49-10 for saline soils. Sodium adsorption ratio along the depth of the two types of soil was ranged from 3.68 to 4.67. Concentrations of soil calcium and magnesium were highest in all soil depths, as opposed to soil potassium. Change of soil cation after the rice harvest is presented in Figure 1, where the Na soil solution was dominant followed by Ca, K, and Mg. Average of soil ammonium (NH_4^+) content was much smaller than the other cations (not shown in the picture). The deeper the soil (20 cm), the increase Ca concentration while the others were almost the same (Figure 1). Soil pH, EC and Na increased with increasing application reciprocal NaCl (Figure 2). The ratio of Ca:Mg and K:Mg also increased with increasing soil Na to exceed the optimum, causing

Table 1. The content of bases in non-saline (T1) and saline (T2) soil solution at a depth of 0-20 cm before the addition of NaCl.

No.	Treatment	pH	Soil Solution Sample						SAR	Ca/Mg	K/Mg
			K	Na	Ca	Mg	Fe	Mn			
			.... mg kg^{-1}								
1	T1 (0-5)	6.63	3.71	36.59	109.00	28.20	0.34	1.35	4.42	3.87	0.13
2	T1 (5-10)	6.18	3.05	36.52	88.50	41.40	0.40	1.38	4.53	2.14	0.07
3	T1 (10-15)	6.53	1.51	36.48	147.00	49.20	0.37	1.37	3.68	2.98	0.03
4	T1 (15-20)	5.88	10.21	36.63	93.00	40.80	0.94	1.43	4.48	2.28	0.25
5	T2 (0-5)	6.52	37.42	36.59	93.50	29.40	0.38	1.41	4.67	3.18	1.27
6	T2 (5-10)	6.08	29.05	36.63	99.50	29.10	0.39	1.43	4.57	3.42	0.99
7	T2 (10-15)	6.58	3.05	36.59	88.00	43.10	0.42	1.56	4.52	2.04	0.07
8	T2 (15-20)	6.07	1.84	36.59	118.00	49.10	0.37	1.47	4.00	2.40	0.04

Note : T1 : non saline soil, T2= saline soil.

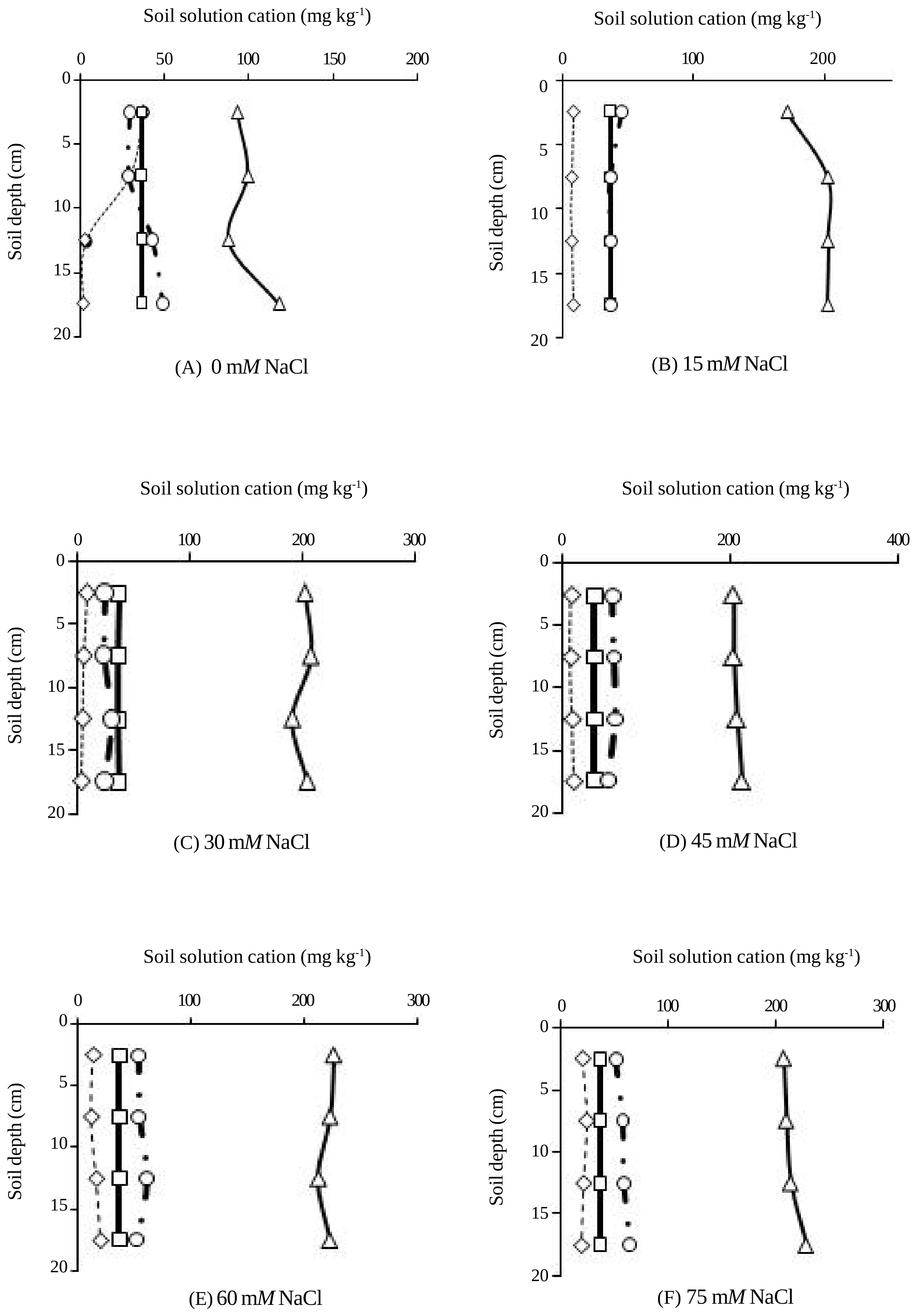

Figure 1. Cations dynamics in 0-20 cm soil depht after harvest on varion dosages of NaCl. ---◇--- = K, —□— = Na, —△— = Ca, and -·-○-·- = Mg.

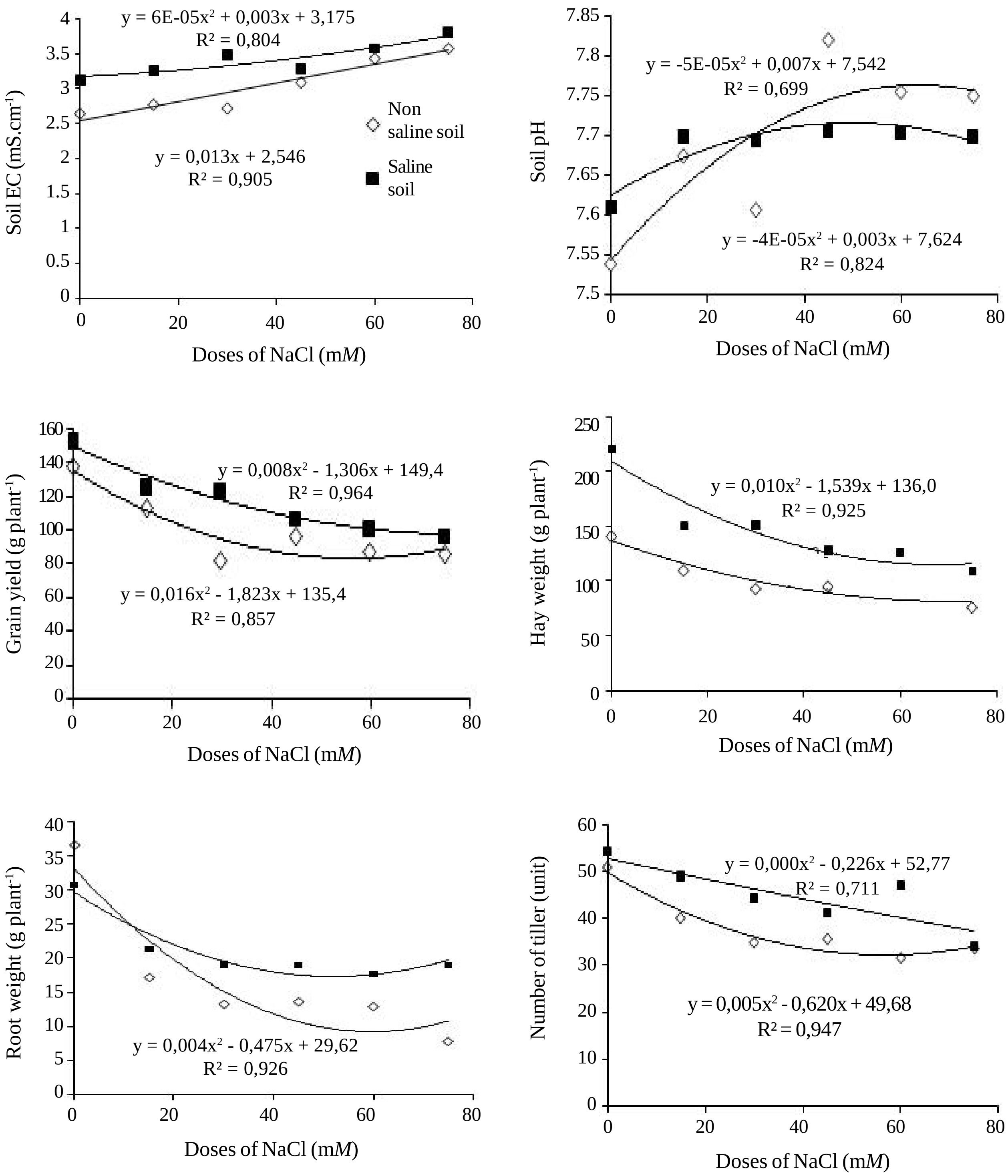

Figure 2. Soil EC, pH, grains, dry weight of rice straw, roots and number of tiller after application of 0-75 m*M* NaCl. ◇ = Non saline soil and ■ = Saline soil.

other cations were not available to the plant which had affected the plant growth.

Rice planted in the nonsaline (T1) and saline soil (T2) had different respond after application of 75 m*M* NaCl. Growth response of rice was not seen after 1 week of NaCl addition, but it growed slowly towards the generative phase. Visually, plant height decreased with high soil salinity up to 75 m*M* NaCl application. Bases content in leaf tissue in the order of Na > K Ca < Mg were good for saline soil and no saline (Figure 1), as found in Carmona *et al.* (2010). Na content of leaf tissue was dominant in all NaCl applications in the range of 3-4 mg kg^{-1} with an average of 3.9 to 4.6% for non- saline soil and between 4.1 to 5.3% for saline soil, followed by Ca content in plants tissue in the range of 0.5 to

Table 2. Ratio soil Ca:Mg before and after NaCl application.

Soil depht	Soil Ca:Mg Ratio												
	Early	+ NaCl (mM), 30 HST						+ NaCl (mM), 90HST					
		0	15	30	45	60	75	0	15	30	45	60	75
0 -5	3.87	5.38	3.78	8.42	3.56	4.22	4.13	4.54	4.00	1.91	3.75	5.61	1.81
5-10	2.14	4.36	5.61	8.90	3.43	4.11	3.70	5.78	9.17	3.33	3.24	4.31	3.24
10-15	2.99	5.61	5.51	6.40	3.41	3.46	3.71	7.35	3.00	3.02	2.67	3.10	4.13
15-20	2.28	4.28	5.50	8.50	4.09	4.27	3.58	6.67	4.17	3.87	6.31	4.93	4.00

Table 3. Anova effect of 0-75 m*M* NaCl treatment and 2 soil type on the soil chemical characteristics and plant growth.

	df	SS	MS	F		Significance F	
						5%	1%
Grain weight	11	21.037.42	1.912.49	3.87	**	2.20	3.11
Straw weight	11	65.959.92	5.996.36	7.88	**		
Root weight	11	2757.27	250.66	681.6977	**		
Number of tiller	11	2.543.00	231.18	3.98	**		
Soil pH	11	0.25	0.02	3.44	**		
Soil EC	11	6.03	0.55	4.14	**		
Soil Ca	11	4361.73	396.52	7.60	**		
Soil Mg	11	21037.42	1912.49	3.8692	**		
Soil Na	11	3248.42	295.31	2.0329	ns		
Soil K	11	1410.50	128.23	44.1740	**		

df = degree of freedom, SS = Sum of Square, MS = Mean of Square.

Table 4. The chemical characteristics of saline soil after application of 0-75 m*M* NaCl.

Treatment	pH	EC $mS.cm^{-1}$	Exchangeable of ($cmol..kg^{-1}$)			
			Ca	Mg	K	Na
Na0	10.10 a	3.85 a	266.33 a	193.33 a	11.17 c	0.174 b
Na1	10.25 c	4.04 b	266.73 a	158.33 b	9.67 b	0.215 c
Na2	10.20 b	4.15 b	272.37 b	135.83 b	8.17 a	0.234 e
Na3	10.35 e	4.25 b	277.27 c	136.00 b	14.67 d	0.226 d
Na4	10.31 d	4.68 c	297.07 e	125.17 b	23.33 e	0.203 b
Na5	10.30 d	4.93 d	291.47 d	121.67 b	27.00 f	0.135 a
LSD 5 %	0.03	0.13	2.61	8.05	0.63	0.003

Table 5. Rice yields in the saline soil after application of 0-75 m*M* NaCl.

Treatment	K	Straw Weight	Grains	Root	Tillers
	…. % ….		…. (g) ….		
Na0	0.174 b	239.83 d	193.33 d	45.02 b	69.83 d
Na1	0.215 d	172.83 c	158.33 c	25.76 a	59.17 c
Na2	0.234 f	162.17 b	135.83 b	21.59 a	52.67 b
Na3	0.226 e	148.33 a	136.00 b	21.77 a	51.00 b
Na4	0.203 c	141.83 a	125.17 a	20.47 a	52.33 b
Na5	0.135 a	123.33 a	121.67 a	17.90 a	45.00 a
LSD5 %	0.003	9.52	7.89	0.22	2.76

Note: Na0= without NaCl , Na1= NaCl 15 m*M*, Na2= 30 m*M* NaCl, Na3= 45 m*M* NaCl, Na4= 60 m*M* NaCl, Na5= 75 m*M* NaCl.

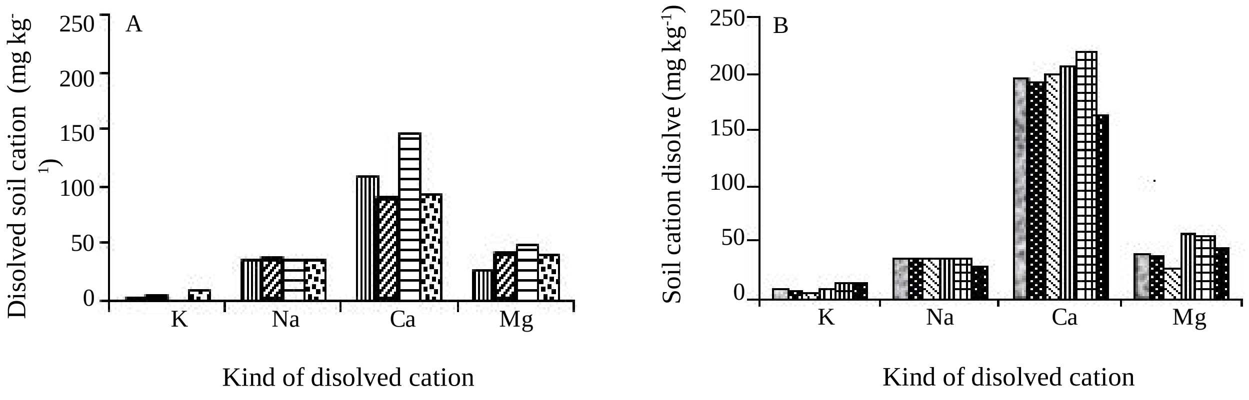

Figure 3. Soil cations average before (A); ▥ = 0-5 cm, ▨ = 5-10, ⊟ = 10-15, ⊞ = 15-20 and a week after NaCl addition (B); ▤ = 0, ▩ = 1, ▧ = 2, ▥ = 3, ▦ = 4, ■ = 5.

Table 6. The chemical characteristics of saline soil after application of 0-75 m*M* NaCl.

Treatment	pH	EC	Exchangeable of.. (me.100g cmol..kg^{-1})			
		mS.cm^{-1}	Mg	K	Na	Ca
T1	10.26 a	4.06 a	133.78 a	14.50 a	0.19 a	274.29 b
T2	10.25 a	4.57 b	156.33 b	16.83 b	0.20 a	282.79 a
LSD 5 %	0.01	0.04	2.68	0.21	0.0010	0.87

Note : T1 : non saline soil, T2= saline soil.

Table 7. Rice yields at two different soil type.

Treatment	Plant - K	straw	grains	root	tiller
T1	0.19 a	133.89	133.78 a	28.29 a	50.22 a
T2	0.20 a	195.56	156.33 b	22.55 b	59.78 b
LSD 5 %	0.001	3.17	2.63	0.07	0.92

Note : SAR = Sodium Absorption Ratio, T1 : non saline soil, T2= saline soil.

1.2%, Mg and K, respectively from 1.7 to 2.2% and 0.2-0.4%. Nitrogen and phosphorus contents of plant tissue were similar in both species and Nitrogen was higher than phosphorus. Dry weight of straw, seeds, and roots and tiller number decreased significantly with the increasing NaCl concentration, but there was no interaction between them (Figure 2 and Table 2, 3, 4, 5, 6 and 7).

DISCUSSION

According to Landon (1984), ratio of Ca:Mg was ideally between 3-4 and K:Mg < 1.5 and it was used to determine the availability of nutrients. In this experiment, we found ratio of Ca: Mg non-saline soil and saline soils were between 2.14 to 3.86 and 2:04 to 3:41, respectively. While the ratio of K: Mg was between 0:03 to 0:13 and between 0:03 to 1:27 for non saline and saline soil, respectively. Value of this ratio was not problematic for the availability of Ca, Mg, and K soil nutrients as close to optimum as the proportion. However, a week after the addition of NaCl at a dose of 0-75 mM circumstances were changed toward dominance of Ca (Figure 3) and the ratio of Ca: Mg increased with increasing the amount of NaCl added, which were between 3.27-8.90 while the ratio K: Mg was hardly changed. Na concentration changed between depths. Presumably the addition of NaCl caused Ca-exchangeable and Ca solution in the soil increased and the Ca: Mg ratio exceeded the optimum limit. Applications of 0.0, 15, 30, 45, 60, and 75 mM NaCl were equal to 0. 0;1.37; 2.74; 4.11; and 5:48; 6.2 mS.cm^{-1} (if 1 mS.cm^{-1} is equivalent to 640 mg kg^{-1}) caused change of soil cations content. The proportion was reversed compared to the previous soil cations. This condition was similar to other experiment in which addition of saline water into the soil increased soil EC to 2-fold from the previous soil EC (Mindari *et al*. 2009). K mobility in sandy textured soil (T1) was higher than the clay-textured soils (T2) from 0-5 up to 15-20 cm. This was in accordance with the opinion of Gacitúa *et al*. (2008).

After NaCl application up to 75 mM, soil solution was saturated with Na^+, and than it was competed with Ca^{+2}, Mg^{+2} K^+, and NH_4^+ for plant uptake and cation exchange places. Mg deficiency occured when other cations dominated the soil, with a low Mg concentrations (<10% base saturation) (Bohn *et al*. 2001 and Korb *et al*. 2005). Plants Mg content were smallest between soluble alkali cations which were suspected by a high alkaline solution would reduce the availability of the other so that its availability decreased. Reduced leaf growth might be due to reduce photosynthesis (Shani and Dudley 2001; da Silva *et al*. 2011) resulting in lower yield rice (Zen and Shannon 2000) due to late seed filling. The yield cation dynamics in this research were likely similar to Carmona *et al.* (2010). Where the higher soil solution Na would decrease rice yield. The Na, K, Ca , Mg and EC levels in the soil solution decreased with time at depths of 5, 10 and 20 cm, regardless of the original soil salinity, showing that cation dynamics in the plow layer was determined by leaching and root uptake, rather than by the effect of evapotranspiration of basic cations in the soil surface layer.

Availability of Mg for rice were small because Mg was relatively resistant to changes, beside soluble Mg could also precipitate from solution and was adsorbed by soil colloids. Na monovalent ions (Na^+) dominated the soil solution, resulting in competition of nutrition uptake with other cations. Na ions that had weakly positive charge was not strong enough to neutralize the negative charge clay particles, causing repel to each other, resulting in a soil without gel structure and plant growth. Provision of NaCl up to 75 m*M* significantly affected straw weight, grain weight, roots and number of tillers. Without addition of NaCl, all parameters of rice yield was higher than if NaCl was added, this indicated that the balance would shift the excess of Na cation lead to reduce availability of Ca, Mg, Na, NH_4^+ as well as caused insufficient supply of plant nutrients. Excess of Na might inhibited photosynthesis thus the seed filling was reduced. The concentration of salt after harvest was average above 2.5 mS cm^{-1} and soil pH above 7, caused by less nutrient availability to plants. The final results obtained that grain decreased with increasing soil salinity. Giving 15 m*M* NaCl was equal to 1.37 mS cm^{-1} , which was ideal for growing ciherang rice and the growth would be reduce if the concentration increased. The height of root weight was comparable to straw weight, grain weight and number of tillers and inversely proportional to concentration of Na. Better root growth would ensure plant growth and yield of rice, and vice versa.

Soil pH increased 0.21 and 0. 9 until 75 m*M* NaCl application respectively in non saline soil and in saline soil, indicated that increasing salt would increase OH^- in soil solution that caused pH increased. In the same media, soil EC increased up to 0.94 and 0.8 $mS.cm^{-1}$ indicated that apart of salt was absorbed by rice and leave. Soil magnesium, ammonium and potassium were smaller than others, it was due to the lack of strong competition with other cation in soil nutrient solution. aplication of Sodium leads to soil equilibrium change, where Na > Ca > Mg > K, that were similar to Carmona *et al.* (2010).

Ratio of Ca: Mg raised above the ideal limit which was 3-4 (Landon 1984) making the availability of other cations disturbed (Table 3). Soils applied with 30 mM NaCl caused soil Ca:Mg ratio increased but decreased nutrient availability. This indicated by the highest content of plants Na than other cations and decreased rice yield. Differance response of soil was determined by soil texture and cation content, where the first soil (non-saline soil from Mojokerto) was sandy while the second soil (saline soil form Gununganyar) was clay. Sandy soil texture was more easily changed with the addition of NaCl compared to clay texture, due to the lower soil buffer capabilities.

CONCLUSIONS

Dynamics of nonsaline soil cations from Mojokerto were different from saline soil Surabaya which were determined by soil texture and cation content. Application of NaCl until 75 mM changed composition of Na, K, Ca, and Mg in soil. The deeper soil layers, exchangeable and solution of Ca were higher than others. Growth and yield of rice were inversely with concentrations of NaCl. The best concentrations of NaCl was about 37 mg kg^{-1} Na, *i.e.* control, according to initial soil conditions before treatment and ratio of Ca:Mg was about 3.

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