Mineral Concentration of Forage Grasses at Different Salinity Levels of Soil

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Abstract

Climatic change increase the sea level that causes soil salinization. High salt concentration in soils inhibits crop growth and production The lower limit of saturation extract electrical conductivity of saline soil is conventionally set at 4 dS m^{-1}. The research was conducted to evaluate mineral concentration of five forage grasses (Panicum maximum, Setaria sphacelata, Euchlaena mexicana, Brachiaria brizantha, and Cynodon plectostachyus) at non saline soil (EC = 0,5 dS m^{-1}) and saline soil (EC= 11 dS m^{-1}). The experiment design in this research using split plot with forage grasses as main plots and different salinity level of soil (non saline and saline) as sub plots. Sodium concentration of herbage increased significantly ($P<0.05$) at saline soil. Herbage nitrogen concentration was not different between non saline and saline soil, except for B. brizantha. Forage grasses had similar concentration of phosphorous at different salinity level of soil, except for S. sphacelata. Potassium concentration of P. maximum S. sphacelata, E. mexicana, B. brizantha, and C. plectostachyus herbage was significantly lower ($P<0.05$) at saline soil. In conclusion, high salt concentration at saline soil reduced potassium uptake. Sodium uptake was higher at saline soil than non saline soil.

Keywords: mineral concentration, saline soil, non saline soil, forage

Introduction

The effect of global warming is climatic change that increase the sea level. It was reported that the increasing of sea level was 3 mm/year. Increasing sea level causes soil salinization along the coast area of island. The sea water that contain high concentration of sodium will be intrusion to the soil along the coast. The high temperature with low rainfall will cause sodium move toward the top soil that affect the plant growth. Abrol (1988) reported the salt affected areas in Indonesia was approximately 13.2 million ha.

Three main groups of salt affected areas are saline soil, saline-sodic soil and sodic soil. Saline soil contains sufficient neutral soluble salts that adversely affect the growth of most crop plants. The soluble salts are mainly sodium chloride and sodium sulfate with EC (electrical conductivity) more than 4 dS/m and ESP (exchange sodium percentage) less than 15. Saline-sodic soil has EC more than 4 dS/m and ESP more than 15. Sodic soil has EC less than 4 dS/m and ESP more than 15 (Majerus, 1996). In relation to crop growth, Abrol (1988) classify soil salinity into five classes. There are non saline soil, slightly saline soil, moderately saline soil, strongly saline soil and very strongly saline soil. Saline soil has EC between 0–2 dS/m, salinity effects are negligible. Slightly saline soil has EC between 2–4 dS/m, yields of sensitive crops may be restricted. Moderately saline soil has EC between 4–8 dS/m, yields of many crops are restricted. Strongly saline soil has EC between 8–16 dS/m, only tolerance crops yield satifactorily. Only a few crops yield satisfactorily at EC more than 16 dS/m or very strongly saline soil.

The effect of soluble salt at soil to plant growth is very complex. Salinity will cause ionic stress, osmotic stress and secondary stress. Accumulation of sodium (Na) and chloride (Cl^-) at leaves harm the plant growth. The high osmotic pressure hampers the plant water uptake, resulting the physiological drought. Excessive sodium ions at the root surface may disrupt plant potassium uptake that is vital for the maintenance of cell turgor, membrane potential and the activity of many enzimes (Xiong and Zhu, 2002). Wang *et al*. (2002) reported the total chlorophyll of elephant grass decrease from 181 at control to 125 at soil with EC 10 dS/m. Increasing NaCl at liquid media from 0 to 100 mM significantly decrease leaf area, chlorophyll content and photosintetic rate of *Leucaena leucocephala* and *Centrosema pubescens* (Kusmiyati *et al.,* 2009a). Salinity also affects nutrient uptake. Kusmiyati *et al.* (2009b) reported increasing NaCl concentration from 0 mM to 300 mM at liquid media significantly decreased nitrogen (N), phosphorous (P) and potassium (K) uptake at shoot and root of elephant grass and king grass.

The experiment was designed to evaluate herbage mineral concentration (nitrogen, phosphorous, potassium and sodium) of *Panicum maximum, Setaria sphacelata, Euchlaena mexicana, Brachiaria brizantha, and Cynodon plectostachyus* at saline soil compare with non saline soil. The obtained results can contribute to a better knowledge of understanding the physiological effect of salinity to develop a tolerant plant.

Materials and Methods

The experiment was conducted at greenhouse in Animal Agriculture Faculty, Diponegoro University, Tembalang Campuss – Semarang. Split plot design with completely random design was used to arrange the experiment. The main plot was forage grasses (R1= *Panicum maximum,* R2= *Setaria sphacelata,* R3= *Euchlaena mexicana,* R4= *Brachiaria brizantha, and* R5= *Cynodon plectostachyus*). The sub-plot was soil salinity level (T1= non saline soil, T2= saline soil). There were three replications.

Pols of each forage grass were planted at pot that contain 10 kg of soil. The first cut was one month after planting to make uniform planting material. Fertilizer dosage are use 60 kg N/ha/cutting, 150 kg P_2O_5/ha and 100 kg K_2O/ha. Grasses were cut 8 weeks after the first cut. Herbage was cut 5 cm above the surface of the soil. Shoot material were weighed and dried in open air for one week. Dried tissues were re-weighed and ground to pass through a 1 mm screen for subsequent tisssue analysis.

Forage N contents were measured by Kjedahl method (AOAC, 1975). Phosphorous was analyzed by spectrophotometer method (Sulaeman *et al*., 2005). While potassium and sodium content were measured by flamefotometry (Sulaeman *et al*., 2005). The mineral concentration (N, P, K, and Na) were calculated in term of g/kg dry matter (DM). The results were analyzed using analysis of variance, then followed by LSD test to compare the different mineral concentration between non saline and saline soil at each forage grass (Steel and Torrie, 1980).

Results and Discussion

Non saline soil was latosol soil that was taken from Tembalang sub district, Semarang city, Central Java. While saline soil was taken from Kaliori sub-district, Rembang–Central Java. Saline soil was classify as alluvial type. Electrical conductivity of saline soil was 11.1±0.35 dS/m with pH 8.3±0.11. According to Abrol (1988), the electrical conductivity of saline sail is classified as strongly saline soil. Non saline soil had EC 0.5±0.01 dS/m and pH 6.81±0.01.

Analysis of variance showed that nitrogen of herbage were significantly different between forage grasses ($P<0.05$) (Table 1). Herbage nitrogen concentration was not different between non saline and saline soil, except for *B. brizantha* (Tabel 1).

Table 1. Nitrogen concentration of grasses at different levels of soil salinity

Grasses	Non saline soil	Saline soil	Mean
P. maximum	18.99±0.38[a]	19.96±0.81[a]	19.48±1.70[a]
S. sphacelata	18.87±0.74[a]	19.00±1.21[a]	18.94±0.90[a]
E. mexicana	18.55±0.84[a]	19.31±0.96[a]	18.93±0.93[a]
B. brizantha	19.42±1.20[a]	14.46±1.58[b]	16.94±3.32[b]
C. plectostachyus	15.62±0.29[a]	15.21±0.54[a]	15.42±0.46[c]
Mean	18.29±1.94[a]	17.59±2.82[a]	

Means followed by a different letter at the same row or column were significantly different at the 0.05 probability level according to LSD test. Number followed by a different letter at the same species of grass was significantly different at the 0.05 probability level according to LSD test.

Nitrogen was absorbed by plant in the form of nitrate (NO_3^-) and ammonium (NH_4^+). Nitrate move to the root surface mainly by mass flow. Mass flow reference to the movement of water together with dissolved electrolytes (ions) through the soil (Tisdale and Nelson, 1975). The reduction of herbage N concentration at saline soil compared with non saline soil of *B. brizantha* and *C. Plectostachyus* were 25% and 2% respectively, while there were no reduction of N concentration at *P. maximum, S. Sphacelata* and *E. Mexicana*

Forage grasses had similar concentration of phosphorous at different salinity level of soil, except for *S. sphacelata* (Table 2). Reduction of phosphorous concentration was ranged from 4% to 10%. Plants absorb most of their phosphorous as the primary orthophosphate ion (H2PO-). Phosphorous moves from soil to roots by ion diffusion process. Plant absorb P by contact exchange (Tisdale and Nelson, 1975). Nitrogen and phosphorus uptake of forage grasses was not different between non saline and saline soil. At saline soil, forage grasses still can absorb nitrogen and phosphorous because the water was available. At this experiment, water at saline soil was maintained at field capacity.

Table 2. Phosphorous concentration of grasses at different levels of soil salinity

Grasses	Non saline soil	Saline soil	Mean
P. maximum	1.79±0.29[a]	1.50±0.29[a]	1.66[bc]
S. sphacelata	1.99±0.05[a]	1.78±0.06[b]	1.89[abc]
E. mexicana	2.46±0.48[a]	2.27±1.07[a]	2.36[a]
B. brizantha	2.21±0.04[a]	2.01±0.80[a]	2.11[ab]
C. plectostachyus	1.44±0.36[a]	1.38±0.21[a]	1.41[c]
Mean	1.98[a]	1.79[a]	

Means followed by a different letter at the same row or column were significantly different at the 0.05 probability level according to LSD test. Number followed by a different letter at the same species of grass was significantly different at the 0.05 probability level according to LSD test.

Potassium concentration of *P. maximum S. sphacelata, E. mexicana, B. brizantha, and C. plectostachyrus* herbage was significantly lower at saline soil ($P<0.05$) (Table 3). Potassium concentration reduction of *P. maximum, S. Sphacelata, E. Mexicana B. brizantha* and *C. plectostachyus* are 48%, 74%, 55%, 55%, and 34%.

Sodium concentration of five grasses herbage increased significantly at saline soil ($P<0.05$) (Table 4). Saline soil has high concentration of NaCl. High salinity in growth media cause excessive sodium at the root surface. Sodium at high concentration has a strong inhibitory effect on potassium uptake by root (Xiong and Zhu, 2002). Sodium and chloride shoot concentration increased and K decreased as the external NaCl concentration increased (Teakle *et al*., 2006). This condition will

Table 3. Potassium concentration of grasses at different levels of soil salinity

Grasses	Non saline soil	Saline soil	Mean
P. maximum	21.19±2.77[a]	10.95±0.91[b]	15.42[b]
S. sphacelata	38.59±4.48[a]	10.01±3.33[b]	24.42[a]
E. mexicana	20.04±3.85[a]	8.90±1.04[b]	14.47[b]
B. brizantha	13.31±0.32[a]	5.97±1.80[b]	9.64[c]
C. plectostachyus	21.56±2.96[a]	14.03±2.62[b]	17.80[b]
Mean	22.94[a]	9.86[b]	

Means followed by a different letter at the same row or column were significantly different at the 0.05 probability level according to LSD test. Number followed by a different letter at the same species of grass was significantly different at the 0.05 probability level according to LSD test.

Table 4. Sodium concentration of grasses at different levels of soil salinity

Grasses	Non saline soil	Saline Soil	Mean
P. maximum	1.15±0.35[b]	6.77±1.65[a]	3.96[c]
S. sphacelata	1.16±0.35[b]	8.86±1.89[a]	5.01[b]
E. mexicana	0.99±0.03[b]	9.09±0.75[a]	5.04[b]
B. brizantha	1.19±0.39[b]	11.63±0.81[a]	6.41[a]
C. plectostachyus	1.15±0.36[b]	10.57±1.34[a]	5.86[ab]
Mean	1.13[b]	9.38[a]	

Means followed by a different letter at the same row or column were significantly different at the 0.05 probability level according to LSD test. Number followed by a different letter at the same species of grass was significantly different at the 0.05 probability level according to LSD test.

cause nutrient imbalances and deficiencies. Paksoy *et al.* (2010) reported K application to plant growth media significantly increased mineral content of okra seedling under saline condition. Tolerant plants had more K uptake than the susceptible ones. Potassium had an important role in salt tolerance (Rubio *et al.* 2004). Salinity will cause ionic stress, osmotic stress and secondary stress. Accumulation of sodium (Na^+) and chloride (Cl^-) at leaves harm the plant growth. Excessive sodium ions at the root surface may disrupt plant potassium uptake that is vital for the maintenance of cell turgor, membrane potential and the activity of many enzimes (Xiong and Zhu, 2002).

The percentage enhancement of sodium concentration were ranged from 488% to 877% at saline soil compared with non saline soil. Sodium concentration at *P. maximum was* 488%, while *B. Brizantha was* 877% at saline soil compared with non saline soil. Among the five grasses that were tested at this experiment, *P. maximum* showed the most tolerant plant. *P. maximum* was capable to suppress the uptake of sodium, also suppressed the reduction of potassium uptake.

Conclusion

It could be concluded that nitrogen concentration in herbage of *Panicum maximum, Setaria sphacelata, Euchlaena mexicana* and *Cynodon plectostachyus* was not different between non saline and saline soil. Herbage phosphorous concentration of *Panicum maximum, Euchlaena mexicana, Brachiaria brizantha, and Cynodon plectostachyus* was similar at non saline and saline soil. High salt concentration at saline soil reduced potassium uptake and increased sodium uptake of *Panicum maximum, Setaria sphacelata, Euchlaena mexicana, Brachiaria brizantha, and Cynodon plectostachyus*. Among the five grasses that were tested at this experiment, *P. maximum* showed the most tolerant plant.

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