MACRO NUTRIENTS UPTAKE OF FORAGE GRASSES AT DIFFERENT SALINITY STRESSES

F. Kusmiyati, E.D. Purbajanti and B.A. Kristanto
Faculty of Animal Agriculture, Diponegoro University,
Tembalang Campus, Semarang 50275, Central Java - Indonesia
Corresponding E-mail : fkusmiyati@yahoo.co.id

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ABSTRACT

The high concentration of sodium chloride (NaCl) in saline soils has negative effects on the growth of most plants. The experiment was designed to evaluate macro nutrient uptake (Nitrogen, Phosphorus and Potassium) of forage grasses at different NaCl concentrations in growth media. The experiment was conducted in a greenhouse at Forage Crops Laboratory of Animal Agriculture Faculty, Diponegoro University. Split plot design was used to arrange the experiment. The main plot was forage grasses (Elephant grass (*Pennisetum purpureum*) and King grass (*Pennisetum hybrida*)). The sub plot was NaCl concentration in growth media (0, 150, and 300 mM). The nitrogen (N), phosphorus (P) and potassium (K) uptake in shoot and root of plant were measured. The result indicated increasing NaCl concentration in growth media significantly decreased the N, P and K uptake in root and shoot of the elephant grass and king grass. The percentage reduction percentage of N, P and K uptake at 150 mM and 300 mM were high in elephant grass and king grass. It can be concluded that based on nitrogen, phosphorus and potassium uptake, elephant grass and king grass are not tolerant to strong and very strong saline soil.

Keywords : nitrogen uptake, phosphorus uptake, potassium uptake, salinity, forage grasses

INTRODUCTION

Land use for forage crops moves towards marginal soil such as saline soil. Saline soil at Java and Sumatra is approximately 400.000 ha mostly widespread at north Java and east Sumatra (Partohardjono and Syam, 1992). Soil utilization of saline soil for agriculture faces many obstacles. The most important problem of saline soil is the high concentration of soluble salts (especially NaCl and Na_2S0_4) that has negative effects on the growth of most plants. Salinity is the concentration of dissolved minerals salts present in water and soils on a unit volume or weight basis (Majerus, 1996).

Abrol *et al*. (1988) classify soil salinity based on conductivity (EC/Electrical Conductivity) and its effect on crop growth. There are 5 classes: (1) non saline soil with conductivity of 0-2 dS/m, salinity effects are negligible, (2) slightly saline soil with conductivity of 2-4 dS/m, yields of sensitive crops may be restricted, (3) moderately saline soil with conductivity of 4-8 dS/m, yields of many crops are restricted, (4) strongly saline soil with conductivity of 8-16 dS/m, only tolerant crops yield satisfactorily, and (5) very strongly saline soil with conductivity of more than 16 dS/m, only a few very tolerant crops yield satisfactorily.

The effect of salinity on plant growth is very complex.. Salinity imposes an ionic stress, an osmotic stress and secondary stresses such as nutritional disorders and an oxidative stress. The high osmotic pressure in saline solutions hampers plant water uptake, resulting in physiological drought. (Flowers, 1977). Sodium (Na^+) excess in soil particles causes expansion and soil pore closing that aggravate gas transfer with in disperse soil colloid materials (Sipayung, 2003). 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 enzymes (Xiong and Zhu, 2002). Leaves of crops growing in saline soil may be smaller and darker blue green in color than the normal leaves. Increased succulence often results from salinity. Plants in saline soil often have the same appearance as plants growing under moisture stress (drought) conditions, although the wilting of plants is far less prevalent (Abrol *et al*., 1988).

Salt stress studies generally have been done in liquid media with complete nutrient solution (Sopandie, 1990). The advantage of using liquid media is easy to maintain the salt concentrations during the research. The salt concentrations are also more precise according to the treatment.

The essential nutrients for crops are sixteen elements that are absorbed from the air and soil. The nutrients that are absorbed from soil can be divided into two classes : macro nutrients and micro nutrients. The macro nutrients are nitrogen (N), Phosphorus (P), Potassium (K) Calcium (Ca), Magnesium (Mg) and Sulphur (S). The crops need huge amounts of macro nutrient for their normal growth (Hakim *et al*., 1986).

The experiment was designed to evaluate macro nutrient uptake (Nitrogen, Phosphorus and Potassium) of forage grasses at different NaCl concentrations in growth media. The obtained results can contribute to better knowledge on forage crop cultivation in saline soil especially about macro nutrient uptake.

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MATERIALS AND METHODS

The research was carried out at Forage Crops Laboratory, Animal Agriculture Faculty of Diponegoro University. Split plot design was used to arrange the experiment. The main plot was forage grasses (Elephant grass (*Pennisetum purpureum*)and King Grass (*Pennisetum hybrida*)). The sub plot was NaCl concentration in growth media (0, 150, and 300 mM). There were 3 replications.

Stem cutting were planted in pots containing sand and compost with comparison of 3: 1. The grasses were cut at four weeks after planting in order to have the same initial growth. Then, the seedlings were transplanted into pots containing complete nutrient solution based on that used by Sopandie (1990).. The complete nutrient solution consists of: $Ca(NO_3)$. $4H_2O$ 1.0 mM; KNO_3 4.0 mM; NH_4NO_3 0.5 mM; KH_2PO_4 1.0 mM; $MgSO_4.7H_2O$ 1.0 mM; $MnSO_4$.H2O 0.05 ppm; $CuSO_4.5H_2O$ 0.02 ppm; $ZnSO_4.7H_2O$ 0.05 mM; H_3BO_3 0.5 ppm and Fe-EDTA 0.034 mM. NaCl was added to nutrient solution based on the treatments. The nutrient solution was aerated continuously and renewed once a week.

The grasses were cut at six weeks after transplanted to the nutrient solution. The nitrogen (N), phosphorus (P) and potassium (K) uptakes in shoot and root of plant were measured. Nitrogen was analyzed by Kjedahl's method (AOAC, 1975). Phosphorus was analyzed by spectrophotometer methods (Sulaiman *et al*., 2005) and Potassium was analyzed by flamefotometry method (Sulaiman *et al*., 2005). The N, P and K uptake in shoot and root were calculated using the following formula :

N uptake in shoot or root = % N x Dry matter of shoot or root

P uptake in shoot or root = % P x Dry matter of shoot or root

K uptake in shoot or root= % K x Dry matter of shoot or root

The results were analyzed using analysis of variance, then were followed by Duncan Multiple Range Test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The electrical conductivity at 0 mM, 150 mM and 300 mM were equivalent to 0 dS/m, 13.7 dS/m and 27.4 dS/m, respectively. The salinity of NaCl concentration in this research can be classified as non saline (0 mM), strongly saline (150 mM) and very strongly saline (300 mM) (Abrol *et al*, 1988).

Nitrogen (N) Uptake

Based on the analysis of variance, concentration of NaCl affected N uptake in shoot and root significantly ($P<0.05$). There were statistical differences of nitrogen (N) uptake in root between the elephant grass and the king grass. It can be seen in Table 1, Duncan's test showed that increasing the NaCl concentration in growth media decreased N uptake in shoot and root significantly ($P<0.05$) . Nitrogen uptake either on shoot or root of elephant grass and king grass at NaCl 150 mM and 300 mM significantly lower than at 0 mM.

Crop absorbs nitrogen in the form of nitrate (NO_3) and Ammonium (NH_4^+). Increasing NaCl from 0

Table 1. Nitrogen Uptake (mg/pot) in Root and Shoot of Elephant Grass and King Grass at Different Concentration of NaCl

NaCl concentration	N uptake in root			N uptake in shoot		
	Elephant grass	King grass	Mean	Elephant grass	King grass	Mean
0 mM	193.2[b]	357.9 [a]	275.5[a]	1512.8[b]	3035.6[a]	2274.2[a]
150 mM	87.9[d]	123.2[c]	105.6[b]	508.4[d]	852.0[c]	680.2[b]
300 mM	61.5[e]	62.6[e]	62.1[c]	333.0[d]	381.4[d]	357.2[b]
Mean	114.2[b]	181.2[a]		784,7	1423.0	

Different superscript in the mean coloumn or row at the same parameter indicated statistically significant differences (P < 0.05)

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mM to 300 mM resulted in the decline of N uptake in shoot and root of grasses. High salinity affects nitrate uptake at two levels : by direct competition of nitrate and chloride (Cl^-) and at the membrane level and/or the membrane proteins by changing plasma lemma integrity (Cramer *et al*., 1985). Saline condition can influence the different steps of N metabolism such as uptake, reduction and protein synthesis (Frechill, 2001). Several biochemical processes are affected by salinity, particularly nitrate assimilation. Nitrate is the most significant source of nitrogen for plants and frequently limits plant growth. Nitrate uptake and nitrate reductase activity (NRA) decrease in plants under salt stress. The addition of 600 $mmol.L^{-1}$ NaCl induced a substantial decline in NRA by about 64% in roots and 52% in leaves (Meloni *et al*., 2004). High salinity also will decrease the nitrification rate (Firestone, 1985).

In order for ions/nutrients to be absorbed by plant roots, they must come in contact with the root surface. There are generally three ways in which this contact is affected. These are contact exchange, diffusion of ions in the soil solution and movement of ions by mass flow of water in the soil. Movement of ions in the soil solution to the surface of roots is an important factor in ion uptake. This movement is accomplished largely by diffusion and mass flow. Mass flow refers to the movement of water together with dissolved electrolytes (ions) through the soil. This movement occurs as a result of rainfall or irrigation but more importantly as a result of the diffusion pressure gradient set up by water absorption by plant roots. Nitrate move to the root surface mainly by mass flow (Tisdale and Nelson, 1975). The primary effect of excess salinity is that it renders less water available to plant (Orak and Ates, 2005). This is because the osmotic pressure of the soil solution increases as the salt concentration increases (Bazzigaluppi *et al*., 2008). The osmotic pressure at 150 mM and 300 mM NaCl were equivalent to 4,932 and 9,864 bars, respectively. Less water available for plant will also reduce the N uptake of plant. High salinity also caused plasmolysis. Plasmolysis will make the root riot so it decreases the ability for absorbing water and nutrient.

Leaves of elephant grass and king grass at 150 mM and 300 mM NaCl were yellowing or chlorosis. This appearance showed that the grasses were deficient in nitrogen. Research by Huffaker and Rains (1985) showed that the growth of barley at saline soil was inhibited because the low uptake of nitrate and ammonium. At the NaCl concentration below 100 mM, the nutrient uptake of barley was not significantly affected. The nitrate uptake at NaCl 200 mM was 17 % from control (0 mM NaCl), while ammonium uptake was 38 %.

The research on saline soil in Semarang showed that N fertilizer of 250 kg N/ha produced 28 % higher dry matter yield of elephant grass than N fertilizer of 150 kg N/ha (Kusmiyati *et al*., 2001). Manure fertilizer and bed type also affect the growth and dry matter yield of elephant grass in saline soil in Semarang. Manure fertilizer equal to 150 kg N/ha and bed type resulted high dry matter yield of elephant grass. Manure fertilizer and bed type also decreased the Na content in saline soil (Kusmiyati *et al*., 2002).

The reduction of N uptake in elephant grass shoot ranged from 66.4 % to 77.9 %, while in root ranged from 54.5 % to 68.2 %. Nitrogen uptake reduction in king grass also high. It ranged from 65.6 % to 82.5 % in shoot and 71.9 % to 87.4 % in root (Table 1). The result showed that elephant grass and king grass are not tolerant to strongly and very strongly saline soil.

Phosphorus (P) Uptake

Phosphorus uptake in shoot and root of grasses at 150 mM and 300 mM NaCl significantly lower than at 0 mM (Table 2). In Elephant grass, P uptake in shoot and root at 150 mM NaCl was not significantly different from that at 300 mM. While in king grass, there was significant difference of P uptake at 150 mM and 300 mM (Table 2).

Phosphorus, nitrogen and potassium, is classified as a major nutrient element. It is generally considered that plants absorb most of their phosphorus as the primary orthophosphate ion (H_2PO^-). Phosphorus uptake is affected by the pH of the medium surrounding the roots. Lower pH values will increase the absorption of the H_2PO^- ion, whereas , higher pH values will increase absorption of the HPO_4^{2-} form. In most soils, phosphorus availability is at a maximum in the pH range from 5.5 to 7.0 , the availabity decrease as the pH drops below 5.5 and also decreases as this values goes above 7.0. Above pH 7.0, the ions of calcium and magnesium cause precipitation of the added phosphorus and its availability decreases (Tisdale and Nelson, 1975). pH of saline soil was around 8.5, the phosphorus availability was low, and so the P uptake was low.

Phosphorus moves from soil to roots by ion diffusion process. Plant absorb P by contact exchange (Tisdale and Nelson, 1975). Salinity affects water and air movement, water holding capacity and root penetration (Qadir *et al.*, 2008). The inhibited water and air movement in saline soil cause the low movement of P from soils to roots, finally the absorption decreases. The low water holding capacity and root penetration also cause decreasing of P uptake by root plant.

Phosphorus affects the root growth of plant, cell differentiation, involved in photosynthesis, assimilation and respiration process (Lakitan, 2000). The low uptake of P will cause the inhibition all those process, so that the plant growth decrease.

The reduction of P uptake in elephant grass root ranged from 56.8 % to 57.8 %, while in shoot ranged from 64.7 % to 68.9 %. Phosphorus uptake reduction in king grass also high. It ranged from 63.2 % to 86.4 % in shoot and 38.6 % to 82.8 % in root (Table 2). The result showed that elephant grass and king grass are not tolerant to strongly and very strongly saline soil.

Potassium (K) Uptake

Potassium uptake in shoot and root of grasses at 150 mM and 300 mM significantly lower than at 0 mM. In Elephant grass, K uptake in shoot and root at 150 mM was not significantly different from that at 300 mM. While in king grass, there was significant

Table 2. Phosphorus Uptake (mg/pot) in Root and Shoot of Elephant Grass and King Grass at Different Concentrantion of NaCl

NaCl concentration	P uptake in root			P uptake in shoot		
	Elephant grass	King grass	Mean	Elephant grass	King grass	Mean
0 mM	325.4[ab]	553.5[a]	439.5[a]	591.6[b]	1137.4[a]	864.5[a]
150 mM	140.6[c]	339.9[b]	240.3[ab]	208.6[d]	418.0[c]	313.3[b]
300 mM	137.4[c]	95.2[d]	116.3[b]	184.2[de]	154.8[e]	169.5[c]
Mean	201.1	329,5		328.1	570.1	

Different superscript in the mean coloumn or row at the same parameter indicated statistically significant differences ($P < 0.05$)
Different superscript in the same coloumn and row at the same parameter indicated statistically significant differences ($P < 0.05$)

difference of K uptake at 150 mM and 300 mM (Table 3).

Potassium reaches the root surface by ion diffusion. As a plant root absorbs nutrients from the surrounding soil solution, a diffusion gradient is set up. This gradient result in the continuous movement of additional ions to the root surface and their absorption by plant (Tisdale and Nelson, 1975). High salinity at growth media cause excessive sodium (Na) ions at the root surface. Sodium at high concentration has a strong inhibitory effect on potassium uptake by root (Xiong and Zhu, 2002). Sodium ions are not required for the plant growth (Tisdale and Nelson, 1975). At high salinity, plant will absorb sodium instead of potassium. Sodium, once enter the cytoplasm has strong inhibitory effect on the activity of many enzymes. (Xiong and Zhu, 2002). Low K uptake will reduce the plant growth. Potassium involved in physiological functions such as carbohydrate metabolism or formation and breakdown and translocation of starch, nitrogen metabolism and synthesis of proteins, control and regulation of activities of various essential mineral elements, activation of various enzymes and adjustment of stomata movement and water relation (Tisdale and Nelson, 1975).

The reduction of K uptake in elephant grass root ranged from 47.8 % to 53.8 %, while in shoot ranged from 74.1 % to 75.3 %. Potassium uptake reduction in king grass also high. It ranged from 71.8 % to 80.1 % in shoot and 73.1 % to 81.9 % in root. The result showed that elephant grass and king grass are not tolerant to strongly and very strongly saline soil. These results were in accordance with Neto et al. (2004). They reported high Na concentration on corn that is planted at NaCl 100 mM. Potassium uptake decrease as much as 36 % at NaCl 100 mM. Wang *et al*. (2002) concluded that elephant grass is sensitive plant to high salinity. The dry matter yield decreased 50 % at EC 25 dS/m.

CONCLUSION

It could be concluded that the nitrogen, phosphorus and potassium uptake in elephant grass and king grass decrease at NaCl concentrations of 150 mM and 300 mM. Based on nitrogen, phosphorus and potassium uptake, elephant grass and king grass are not tolerant to strongly and very strongly saline soil.

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Table 3. Pottasium Uptake (mg/pot) in Root and Shoot of Elephant Grass and King Grass at Different Concentrantion of NaCl

NaCl concentration	K uptake in root			K uptake in shoot		
	Elephant grass	King grass	Mean	Elephant grass	King grass	Mean
0 mM	90.3^b	265.4^a	177.9^a	1873.2^b	3289.1^a	2581.2^a
150 mM	47.1^c	71.5^b	59.3^b	485.4^d	933.3^c	709.35^b
300 mM	41.7^c	47.9^c	44.8^b	463.1^{de}	653.1^e	558.1^b
Mean	59.7	128.3		940.6^b	1625.2^a	

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