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FULL PAPER

Grain Yield and Cation Uptake of Selected Corn (*Zea mays* L.) Varieties Under Saline Soil with Supplemental Potassium Fertilization

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A field experiment was conducted in saline soil to determine the effect of soil salinity and potassium (K) application on the uptake of different bases (Calcium (Ca), Magnesium (Mg), potassium (K), Sodium (Na)) in selected corn (Zea mays L.) varieties. The experiment was laid out in RCBD with variety as mainplot and fertilizer rate as subplot. Soil salinity severely affected the performance of the three varieties. However, the application of additional K improved their agronomic characteristics which resulted to increase in yield. IPB Var 11 showed better performance compared to the other varieties tested. Cation concentration in corn stover and grains of the varieties planted in saline soil were significantly affected by application of additional K. Total Ca, Mg, Na uptake was reduced while K uptake was increased with the supplemental application of K. The increase in availability of K in soil due to supplementation with K affected the interaction between the different nutrient cations. Ca:Mg ratio, Ca:K ratio, Mg:K ratio was reduced due to increase in total potassium uptake. Na:K ratio of IPB Var. 11 was lower compared to the other varieties in all fertilizer levels which explain its inherent characteristic to be saline tolerant. Proper nutrient management like application of additional K coupled with proper choice of variety can alleviate the adverse effect of soil salinity in corn production.

Keywords: cation concentration, cation uptake, grain yield, nutrient ratio, soil salinity

INTRODUCTION

Soil salinity is one of the major constraints in crop production. With recent changes in climatic conditions as a result of climate change, there are reports on the increasing incidence of this abiotic stress. General estimates are close to about 1 B ha or about 7% of the Earth's continental extent with 77 M ha having been salinized as a consequence of human activities (Haruyama et al. 2006). On the average, 20% of the world's irrigated land is affected by salts and roughly 11M ha are in Southeast Asia (Abdelfattah et al. 2009). In the Philippines, almost all saline soils are located in coastal areas, estimated to be around 400,000 ha or about 1.33% of the total land area (Guerrero 1977).

Corn is the second important cereal crop worldwide, and there is an increasing interest in shifting to corn farming due to its demand and high price. In the Philippines, there are about 2.65 M ha harvested to corn in 2007, constituting about 27% of the total area devoted to agriculture (BAS 2007). Corn production in the country comprised of both white and yellow corn with the annual average yield of 2.66 tons ha^{-1}. With recent improvement and release of new varieties and hybrids, there is more interest on yellow corn production due to its use as feedstuff.

Like any other crop, corn is highly responsive to chemicals, fertilizers and environmental conditions. One of the limiting factors in corn production is environmental stress. Problem on soil salinity is further intensified in the field due to unfavorable weather condition and most drought prone regions located in coastal areas are also identified to be salt-affected areas. Soil salinity can significantly reduce corn yield up to 75% depending on the level of salinity (FAO 2005). The ideal threshold electrical conductivity (EC) value for corn production is 2.0 dS m^{-1} and higher values will result in significant yield reduction or plant death at early emergence (Kotuby-Amacher et al. 2000). Excessive presence of salts in the field affects plants mainly through toxicity from excessive uptake of sodium (Na) that alters plant osmotic pressure especially in areas with high evaporation rate, low precipitation, and through reduction in uptake of nutrients particularly K (Cakmak 2005). Salt-affected areas with high levels of Na and low levels of K, Ca and Mg have poor soil structure. There are also reports on the interaction of salinity with other nutrient like Cadmium (Cd) and Boron (B) (Jafari et al. 2009).

Excessive amounts of soluble salts in the root cause osmotic stress that leads in disturbance of plant water relations, in the uptake and utilization of essential nutrients and also in toxic ion accumulation. Interaction of salts with other mineral nutrients leads to nutrient imbalances and deficiencies. Imbalance occurs in cells due to excessive accumulation of Na^+ and Cl^- and reduces the uptake of other nutrients such as K, Ca and Mg (Karimi et al. 2005). High Na/K ratio can accumulate due to high amount of Na in soils which inactivates several enzymes and affects metabolic processes in plants. Potassium is necessary for osmoregulation and protein synthesis while Ca is required in maintaining cellular integrity and proper functioning of cell membranes. Mg on the other hand is an important component of chlorophyll which is directly involve in photosynthesis (Carden et al. 2003). According to Weimberg (1987) high levels of Na inhibit K uptake causing increase in Na:K ratio. High K:Na selectivity in plants under saline conditions has been suggested to be an important criterion in selecting cultivars for salt tolerance (Ashraf 2002).

Proper fertilization in areas grown to corn is not well addressed. Farmers still follow the conventional rate of fertilizer application in spite of some findings that additional K may reduce the effect of soil salinity on corn. However, Cakmak's (2005) recommendation to apply K fertilizer to improve corn yield in saline soils should be further studied.

While the effect of salinity on lowland rice is well-studied, corn cultivation in saline areas have not been given proper attention. Limited studies are being conducted on the effect of salinity on corn production in the Philippines. Hence, the effect of salinity on corn production and the development of proper fertilization practices, particularly K application, should be addressed to enhance or sustain corn productivity in saline soils.

This study was conducted to determine the effect of soil salinity and K application on the productivity of three yellow corn varieties. The uptake of Ca, Mg, Na and K and cation uptake ratios (Na:K, Na:Ca, Na:Mg, Ca:Mg, Ca:K and Mg:K) due to additional K were also compared.

MATERIALS AND METHODS

A field experiment was conducted on a San Manuel silt loam soils located at Sitio Bateng East, Mangaldan Pangasinan during the months of November 2012 to April 2013. Experimental location belongs to Type I climate with distinct wet and dry season. Wet season covers the months from May to September and dry season from the months of October to April.

San Manuel silt loam covers about 65,219 ha based on the total land area of Pangasinan. Soils classified under San Manuel series may have originated from old alluvium, recent alluvium and recent coastal deposits (Fernandez and de Jesus,1980).

Soil in the area (Table 1) has relatively neutral pH with moderate amount of organic matter (OM) from the surface down to 40 cm depth. Electrical conductivity (EC_e) was high indicative of its high salinity level and increased with depth. Nitrogen (N) level ranges from medium to low and decreased with depth while Phosphorus (P) was moderate in both layers. Exchangeable K was high in both soil layers while exchangeable Ca which was higher than exchangeable Mg and Na were at moderate levels. Cation exchange capacity (CEC) of the soil ranges from 34.15-35.42 $cmol_c$ kg^{-1} with approximately 90% base saturation. The exchangeable sodium percentage (ESP) was low with Na adsorption ratio of about 0.40.

Table 1. Initial soil chemical analysis of the field used for the experiment

Soil Parameter	Soil Depth 0-20 cm	 21-40 cm
pH	6.73	6.65
Electrical Conductivity EC (dS m^{-1})	14.16	16.9
Organic Matter (%)	2.71	2.44
Total Nitrogen (%)	0.15	0.12
Available Phosphorus (Bray, ppm)	12.62	10.45
Exchangeable Potassium (cmolc kg^{-1})	2.16	2.12
Exchangeable Calcium (cmolc kg^{-1})	16.1	16.61
Exchangeable Magnesium (cmolc kg^{-1})	11.26	12.14
Exchangeable Sodium (cmolc kg^{-1})	1.36	1.44
Cation Exchange Capacity (cmolc kg^{-1})	34.15	35.42
Base Saturation (%)	90.44	91.22
Exchangeable Sodium Percentage (%)	5.12	5.16
Sodium Adsorption Ratio	0.39	0.4

Table 2. Grain yield of three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer Rate	Grain yield (t ha^{-1}) IPB Var. 11	 SYQ6	 IPB Var. 7
Control (0-0-0)	0.43d	0.37d	0.40d
140-70-70	1.32ab	1.00c	1.13bc
140-70-105	1.41a	1.05c	1.14bc

cv(%)=7.98; Means followed by the same letters are not significantly different at 5% level of significance using Tukey test

Three yellow corn varieties were assigned to main plots and three fertilizer combinations to the subplots. The treatment combinations were laid out in RCBD with four replications. The three yellow corn varieties used were IPB Variety (Var.) 11 (IPB Composite 3), an open pollinated variety (OPV) which has been identified to be potentially saline and drought tolerant; SYQ 6, a synthetic yellow QPM variety from CIMMYT which can load more protein to its grains; and IPB Variety 7 which is a check variety in terms of yield. Fertilizer combinations included were: (i) control (no fertilizer applied); (ii) 140N-70P_2O_5-70K_2O (recommended fertilizer rate for corn); and (iii) higher K rate, 140N-70P_2O_5-105K_2O. The additional 35 kg K_2O application and timing of application used for the experiment were based on existing practice in the region. Half of the N rate and all the P and 70kg K_2O per hectare were applied at basal (2 and 3), while the remaining N (2 and 3) and additional 35 kg K_2O per hectare (3) were side dressed at 30 days after planting (DAP).

Plot size for the experiment was 4.2 m x 4 m, with 0.70 m as furrow distance and 20 cm as planting distance. One-meter alley was maintained between experimental plots. The designated sampling area was 2.8 m x 3 m. Two seeds were planted per hill and then thinned to one plant per hill at 2 wk after planting. Five plant samples were harvested at 110-115 d after planting (DAP) for analysis of yield component and cation uptake.

Agronomic parameters collected were plant height, total crop biomass, 100-seed weight, harvest index and yield. Composite samples of corn stubbles and grains from five harvested plants were analyzed for Ca, Mg, K and Na concentration.

Data collected were subjected to ANOVA procedure using SAS v6.12. Treatment means were compared using Tukey Test at 5% level of significance. Correlation of means for nutrient uptake and other parameters were also determined.

Grain Yield

The yield of the three varieties used for the experiment was limited by the high soil salinity problem which was observed to be around 14-16 dS m^{-1}. Grain yield was generally higher in IPB Var. 11 as compared to the other varieties for all fertilizer rates and this can be attributed to its inherent drought and saline tolerance. Highest grain yield was observed in IPB Var. 11 fertilized with additional 35 kg K_2O resulting to a mean grain yield of 1.41 t ha^{-1} (Table 2) under saline condition. This yield however is significantly lower compared to its average yield of 4.00 t ha^{-1} under normal condition. This result confirms the previous studies conducted by Monsour et al. (2005) and Eker et al. (2006) that different varieties of corn have variable response to soil salinity. According to Maas and Hoffmann (1977), corn is considered as salt sensitive cereal crop with yield reduction varying from 10% at an EC_e of 1.7 and 50% at EC_e of 7 dS m^{-1} while Dobbermann and Fairhurst (2000) observed yield reduction in rice by 10-15% at EC_e of >4 dS m^{-1} and more than 50% yield reduction at EC_e >10 dS m^{-1}. The application of additional K also increased grain yield for all varieties and there was significant interaction between variety and fertilizer application. The mean grain yield in the control plots was 0.40 t ha^{-1} while there was no significant difference in grain yield of conventional fertilizer rate (140-70-70) and those with additional K (140-70-105). Conventional fertilizer rate with additional K increased grain yield by 50 kg ha^{-1} in SYQ6 and IPB Var. 11 over conventional fertilizer rate alone.

Total Dry Matter Accumulation

Conventional fertilizer rate (140-70-70) plots produced significantly higher plant biomass over the control plots. The mean plant biomass for the conventional fertilizer rate was 3.01 t ha^{-1} while it was 1.42 t ha^{-1} in control plots (Table 3). Additional K did not increase total biomass of all the varieties. The total biomass was relatively low for all varieties since the initial effect of salts is similar in drought as it reduced the ability of plants to absorb water which led to lower growth (Munns, 2002).

Table 3. Total plant biomass of three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer Rate	Total Crop Biomass (t ha^{-1})			Mean
	IPB Var 11	SYQ6	IPB Var 7	
Control (0-0-0)	1.43b	1.43b	1.39b	1.42b
140-70-70	3.14a	2.98a	2.90a	3.01a
140-70-105	3.16a	2.95a	2.98a	3.03a

cv(%)=3.80; In a column for each parameter, means followed by the same letters are not significantly different at 5% level of significance using Tukey test

Table 4. Harvest index of three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer Rate	Harvest Index		
	IPB Var 11	SYQ6	IPB Var 7
Control (0-0-0)	0.3	0.26	0.29
140-70-70	0.42	0.34	0.39
140-70-105	0.44	0.36	0.38

Harvest Index

The harvest index of the three varieties grown under saline condition ranges from 0.26-0.44 (Table 4). Among the varieties, IPB Var. 11 had higher harvest index compared with the other varieties in all fertilizer treatment plots; it has the highest yield across fertilizer-applied plots. Harvest index of 0.44 was observed in IPB Var. 11 fertilized with additional K. Compared to the results obtained by Akram et al. (2010), however, these values were relatively higher since the harvest index they observed ranged from 0.20-0.26 using two hybrid varieties with varying levels of potassium. Ideally, the harvest index value for corn ranged from 0.20 to 0.60. A high harvest index indicates a superior conversion of dry matter to grain yield for rice according to Ismail (1993).

Concentration and accumulation of different cations in corn stover and grains

Potassium accumulation

Potassium concentration in stover and grain of the three varieties increased with additional K application (Table 5). The level of potassium in corn stover ranged 8.59-30.29 kg ha^{-1}, while 1.18-5.58 kg ha^{-1} in grains. IPB Var. 11 had the highest K concentration in both stover (30.29 kg ha^{-1}) and grains (5.58 kg ha^{-1}) in all fertilizer treatment particularly in plots with additional K and exhibited a significant increase in K concentration with additional K. Application of additional K significantly increased the total K uptake of the three test varieties. According to Mengel and Kirby (2001), K is essential for many physiological processes such as photosynthesis, translocation of photosynthates into sink, activation of enzymes and more importantly reducing the excess uptake of Na in saline soil. Morgan (1992) reported that wheat lines displaying high osmotic adjustments had high accumulation of K in their tissues.

Sodium accumulation

Unlike K concentration, Na level in corn stover and grains were reduced upon application of additional K which leads to confirmation of the antagonistic effect of K to Na (Hu and Schmidhalter, 2005). Generally, Na concentration in corn stover was lower in IPB Var.

Table 5. Potassium concentration of the three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer rate	IPB Var 11	SYQ6	IPB Var 7	Mean
		Stover (kg ha^{-1})		
Control (0-0-0)	9.15c	10.39c	8.59c	9.38c
140-70-70	26.39b	22.05b	21.13b	23.19b
140-70-105	30.29a	24.86a	24.14a	26.52a
		Grains (kg ha^{-1})		
Control (0-0-0)	1.24c	1.18b	1.31b	1.25c
140-70-70	4.58b	3.60a	4.01a	4.06b
140-70-105	5.58a	4.08a	4.29a	4.65a
		Total (kg ha^{-1})		
Control (0-0-0)	10.39c	11.50c	10.15c	10.68c
140-70-70	30.98b	25.65b	25.33b	27.32b
140-70-105	35.87a	28.94a	28.70a	31.17a

In a column for each parameter, means followed by the same letters are not significantly different at 5% level of significance using Tukey test

Table 6. Sodium concentration of the three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer rate	IPB Var 11	SYQ 6	IPB Var 7	Mean
		Stover (kg ha^{-1})		
Control (0-0-0)	4.99b	5.06c	5.26b	5.10c
140-70-70	13.90a	17.18a	17.13a	16.07a
140-70-105	12.72a	14.50b	16.85a	14.69b
		Grains (kg ha^{-1})		
Control (0-0-0)	0.47b	0.50b	0.48c	0.48b
140-70-70	1.95a	1.76a	1.99a	1.90a
140-70-105	1.97a	1.80a	1.72b	1.83a
		Total (kg ha^{-1})		
Control (0-0-0)	5.46b	5.70c	5.83b	5.66c
140-70-70	15.86a	18.93a	19.41a	18.07a
140-70-105	14.70a	16.29b	18.57a	16.52b

In a column for each parameter, means followed by the same letters are not significantly different at 5% level of significance using Tukey test

Table 7. Calcium concentration of the three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer rate	IPB Var 11	SYQ 6	IPB Var 7	Mean
		Stover (kg ha^{-1})		
Control (0-0-0)	61.09b	59.22c	49.95b	56.76b
140-70-70	184.39a	170.10a	141.11a	165.20a
140-70-105	171.21a	143.62b	131.97a	148.93b
		Grains (kg ha^{-1})		
Control (0-0-0)	2.44b	2.87b	2.30b	2.54b
140-70-70	40.93a	30.19a	29.93a	33.68a
140-70-105	39.41a	26.59a	25.90a	30.63a
		Total (kg ha^{-1})		
Control (0-0-0)	63.54b	63.18c	54.62b	60.45c
140-70-70	225.32a	200.29a	170.62a	198.75a
140-70-105	210.62a	170.20b	157.87a	179.56b

In a column for each parameter, means followed by the same letters are not significantly different at 5% level of significance using Tukey test

11 compared to other varieties in any fertilizer treatment (Table 6). However, only in SYQ6 was significant reduction in Na uptake was observed upon application of additional K. Meanwhile, Na concentration in grains was relatively lower compared to K, with concentration ranging 0.47 – 1.99 kg ha^{-1}. Sodium concentration was also reduced in both SYQ6 and IPB Var 7, however, only IPB Var 7 showed significant reduction in plots with additional K.

Overall, higher K application reduced the total Na concentration in all varieties regardless of the fertilizer rate. The application of K may restrict root uptake of toxic ions like Na and control the movement of Na to

Table 8. Magnesium concentration of the three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer rate	IPB Var 11	SYQ 6	IPB Var 7	Mean
		Stover (kg ha^{-1})		
Control (0-0-0)	32.88b	35.90b	26.29c	31.69b
140-70-70	157.86a	129.53a	93.26b	126.88a
140-70-105	148.37a	115.83a	119.71a	127.97a
		Grains (kg ha^{-1})		
Control (0-0-0)	2.30b	2.53b	3.31c	2.71b
140-70-70	25.22a	17.04a	21.94a	21.40a
140-70-105	23.38a	21.14a	14.05b	19.53a
		Total (kg ha^{-1})		
Control (0-0-0)	35.18b	35.83b	29.67b	33.56b
140-70-70	183.08a	146.57a	120.65a	150.10a
140-70-105	171.76a	136.97a	133.76a	147.50a

In a column for each parameter, means followed by the same letters are not significantly different at 5% level of significance using Tukey test

Table 9. Nutrient ratio of the cations of the three corn varieties grown on saline soil with increasing potassium rate.

Fertilizer rate	IPB Var. 11	SYQ 6	IPB Var. 7
	Na:K Ratio[a]		
0-0-0	0.52c	0.50c	0.59b
140-70-70	0.51c	0.74a	0.77a
140-70-105	0.41d	0.56b	0.65ab
	Na:Ca Ratio[b]		
0-0-0	0.087b	0.090b	0.110a
140-70-70	0.071c	0.096b	0.116a
140-70-105	0.071c	0.098b	0.118a
	Na:Mg Ratio[b]		
0-0-0	0.159b	0.159b	0.201a
140-70-70	0.087c	0.131b	0.163a
140-70-105	0.086c	0.119b	0.145a
	Ca:Mg Ratio[c]		
0-0-0	1.85a	1.78a	1.92a
140-70-70	1.25a	1.38b	1.46b
140-70-105	1.24a	1.25b	1.22b
	Ca:K Ratio[c]		
0-0-0	6.19b	5.52b	5.35b
140-70-70	7.26a	7.84a	6.73a
140-70-105	5.91b	5.90b	5.50b
	Mg:K Ratio[c]		
0-0-0	3.46c	3.11c	3.06b
140-70-70	5.92a	5.74a	4.76a
140-70-105	4.80b	4.73b	4.65a

[a] there is a significant interaction between variety and fertilizer rate, Means followed by the same letters are not significantly different at 5% level of significance using Tukey test;

[b] In a row, for each parameter, means followed by the same letter are not significantly different at 5% level of significance using Tukey test;

[c] In a column, for each parameter, means followed by the same letter are not significantly different at 5% level of significance using Tukey test;

the shoot by controlling their influx into the root xylem (Wei et al. 2003). Another underlying mechanism of Na accumulation is the maintenance of adequate levels of K under salt stress which is dependent upon selective K uptake and selective K and Na compartmentalization and distribution in the shoots (Carden et al. 2003).

Calcium accumulation

Highest Ca (184.39 kg ha^{-1}) concentration in corn stover was observed in IPB Var. 11 planted in fully fertilized plots. A similar trend was also observed for Ca concentration in grains. Fertilizer application significantly increased Ca concentration but with additional application of K the concentration of Ca in grain decreased, although the difference was not significant). The highest Ca concentration in grain was also observed in IPB Var. 11 which was grown on recommended fertilizer rate plots (Table 7).

In terms of total Ca uptake of the three varieties under the different fertilizer rate, similar trend was also observed just like in stover and grains. The addition of nutrients according to Hu and Shmidhalter (2005) can either enhance or decrease the plants tolerance to drought or salinity or have no effect at all. Results from the present study revealed that the addition of fertilizer enhanced the Ca uptake however the application of additional K reduced the Ca uptake. Intracellular Ca regulates the plant response to drought and salinity and regulates the transduction of salt-stress signals for osmoregulation under saline conditions (Bartels and Sunkar 2005). Calcium uptake under saline condition can be reduced due to the increase in its ionic strength which limits its activity (Cramer 2002).

Magnesium accumulation

Like in Ca, Mg accumulation in both stover and grains was significantly increased upon fertilizer application (Table 8). Increasing the rate of applied K decreased the Mg concentration in stover of IPB Var. 11 and SYQ 6. Only in IPB Var. 7 was a significant increase in Mg accumulation in stover was noted. Magnesium concentration in grains of IPB Var. 11 and IPB Var. 7 were reduced in plots with higher K rate,but was only significant in IPB Var. 7. QComposite 6 on the other hand, exhibited increased Mg accumulation in its grain with higher K rate, although the increase is insignificant. In terms of total Mg accumulation, both IPB Composite 3 and SYQ 6 showed a decrease in total Mg uptake with higher K rate. In contrast with the two varieties, IPB Var. 7 showed an increase in total Mg accumulation with increased K rate. Bar-Tal et. al. (2002) also observed a decrease in Mg concentration in plant tops with application of additional K and such was attributed to the antagonistic effect of K on Mg uptake in corn plants.

While limited studies on the Mg nutrition as affected by salinity were done, Hu and Schmidhalter (1997) reported a correlation between wheat yield and Mg accumulation in plant under saline condition. They also suggested that supplemental Mg could play a role in increasing plant salt resistance when this nutrient is available at low levels.

Nutrient Ratio of Different Cations in Corn

Sodium: Potassium Ratio

The Na:K ratio was significantly affected by the interaction between varieties and fertilizer rates. IPB Var. 7 had the highest Na:K ratio regardless of the fertilizer rate, while IPB Var. 11 had the lowest in the recommended fertilizer rate and in high K rate. The highest significant Na:K ratio was observed in IPB Var. 7 and SYQ 6 in recommended fertilizer rate plots with mean Na:K ratio of 0.767 and 0.738 respectively. The lowest Na:K ratio was observed in IPB Var. 11 when applied with higher K and its mean Na:K ratio was 0.408. Application of higher K decreased Na:K ratio since it resulted to increased K accumulation and decreased Na accumulation. Potassium is important in maintaining the turgor pressure in plants under salt stress and plants should manifest preference for K over Na resulting to lower Na:K ratios to improve the resistance of plant to salinity (Asch et al. 2000). Reversing Na:K ratio would mean for plant to show tolerance to salinity, thus K:Na ratio should increase.

Sodium:Calcium Ratio

The Na:Ca ratio differed among varieties across fertilizer rate. IPB Var. 7 had the highest Na:Ca ratio among fertilizer rates but control plots showed higher ration than fertilized plots. Total Ca and Na concentrations decreased with the application of greater amount of K which resulted in insignificant change in Na:Ca ratio. No increase in Na:Ca ratio was observed in IPB Var. 11 with higher K rate since the concentration of Na in IPB Var. 11 is generally lower compared to other varieties. The inherent genotypic trait to maintain Ca in tissues and to exclude Na from the shoots that results to low Na:Ca ratio are highly heritable traits, such that Na:Ca ratio could be an important indicators of salt resistance in plants as claimed by Fooland (1997).

Sodium:Magnesium Ratio

The Na:Mg ratio significantly differed among varieties regardless of the fertilizer rate, with IPB Var. 7 showing significantly higher ratio compared to other varieties across fertilizer rates. On the other hand, IPB Var. 11 had the lowest Na:Mg ratio, especially under recommended fertilizer rate and high K rate. Furthermore, application of higher K rate decreased the Na:Mg ratio for the three varieties due to the decrease in Na concentration with application of additional K.

Calcium:Magnesium Ratio

The Ca:Mg ratio in the three varieties were significantly reduced by fertilizer application. There was a positive correlation (R^2=0.82, $P<0.001$) between total Ca and Mg concentration. However, increasing K rate reduced the total Ca and Mg concentrations which resulted to lower Ca:Mg ratio. In rice, the ideal Ca:Mg ratio in shoot is 1-1.5:1 according to Dobermann and Fairhurst (2000).

Calcium:Potassium Ratio

Tha Ca:K ratio was significantly increased by fertilizer application and decreased significantly with the application of higher K rate. This is brought by the decrease in total Ca concentration, but an increase in total K concentration in the three test varieties applied with higher K rate. Excessive K fertilization in rice results to wide Ca:K ratio and reduced Ca uptake as reported by Dobermann and Fairhurst (2000).

Magnesium:Potassium Ratio

The Mg:K ratio of the three varieties ranged 3.06-5.92. Fertilizer application also significantly increased the Mg:K, like in the case of Ca:Mg and

Ca:K. Application of higher K rate decreased the Mg;K ratio since the concentration of Mg decreased while simultaneously K concentration increased. The significant decrease in Mg:K ratio in plots with higher K rate was apparent in IPB Var. 11 and SYQ 6. For IPB Var. 7, there was a slight increase in Mg concentration. The antagonistic effect of K towards Mg may have caused the reduction in Mg:K ratio of all varieties upon application of higher K rate.

CONCLUSION AND RECOMMENDATION

Soil salinity severely affected the potential yield of the varieties used for the field experiment. Grain yield and total biomass of the three varieties increased with increasing the amount of K relative to the control treatment. IPB Var. 11 showed better performance compared to other varieties under saline condition since it had higher yield and total crop biomass. In general Ca and Mg concentrations were higher than K and Na concentrations in corn stubbles of all varieties grown under saline condition. Increasing the amount of applied K brought a decrease in the percentage of all other cations. While Ca, Mg and K concentration of IPB Var. 11 stubbles was higher compared to other varieties, Na concentration was significantly lower in this variety. Cation concentration in the grains followed the same trend as the corn stubbles but with generally lower concentration. Total uptake of Ca, Mg and Na was reduced while K uptake increased with increasing amount of K due to increased availability of K in soil. Results suggest that application of higher amount of K which resulted in increase in total K uptake reduced the effect of soil salinity thereby increasing yield in all varieties. Nutrient uptake ratio of the different cations was also affected by higher K rate. Na:K ratio in most plant can serve as indicator for salt tolerance as in the case of IPB Var. 11 which showed higher K and lower Na uptake in fertilized plots compared to other varieties. This result confirms the inherent characteristic of IPB Var. 11 to be more tolerant to soil salinity. The result of the study showed that proper nutrient management like increasing the amount or rate of K coupled with proper choice of variety can alleviate the adverse effect of soil salinity in corn cultivation

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