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Short Communication

Regulation of plant Na/K ratio for productivity enhancement in *Pokkali* rice

Emily Alias[1], Deepa Thomas[2*], Meera V. Menon[3], P. Prameela[4] and A.K. Sreelatha[5]

[1,3,4]*College of Horticulture, Kerala Agricultural University, Thrissur 680 656, Kerala, India*
[2]*Aromatic and Medicinal Plants Research Station, Kerala Agricultural University, Odakkali 683 549 Kerala, India*
[5]*Rice Research Station, Kerala Agricultural University, Vyttila 682 019, Kerala, India*

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Abstract
Pokkali is a unique rice farming system in coastal saline soils of Kerala. High Na content and the resultant wide ratio between Na and other cations, especially K, within the plant become detrimental for rice crop in these soils. An experiment was conducted at Rice Research Station, Vyttila during *kharif* 2018 to study the effect of liming and foliar application of K in reducing the Na/K ratio in *Pokkali* rice, adopting Randomised Block Design with 10 treatments replicated thrice and saline tolerant rice variety Vyttila 8. Treatments included two levels of lime (500 and 1000 kg ha^{-1}) or dolomite (800 and 1600 kg ha^{-1}) alone, and in combination, with foliar spray of sulphate of potash (SOP), 2% at 20 and 40 days after transplanting (DAT), foliar spray of SOP alone and control. The study indicated that application of lime at higher quantity, and foliar spray of SOP had significant influence on reducing the plant Na/K ratio. Number of tillers and panicles per m^2, percentage of filled grain and grain yield were found to be higher on lime application @1000 kg ha^{-1} in combination with foliar spray of SOP, thereby enhancing the economic returns. Correlation analysis showed that grain yield and number of panicles had significant negative correlation with Na/K ratio at flowering. It was observed that flowering stage was the most critical one for maintaining a low Na/K ratio, which could influence the crop yield significantly.

Key words: Acid saline soils, Plant Na/K ratio, *Pokkali* rice, Salinity.

Pokkali is a unique and sustainable rice farming system in coastal saline soils of Kerala, and *Pokkali* rice is recognized as the most saline tolerant rice variety of the world. This ecosystem is highly vulnerable to soil and climatic conditions such as soil acidity, high tidal waves causing saline water intrusion to crop fields, high intensity rainfall and crop submergence. Soils of *Pokkali* are deep, impervious, clayey, rich in organic matter, acidic with a pH ranging from 3.1- 4.8 but of high salinity due to tidal inundation. Electrical conductivity of soil during summer months ranges from 12 to 24 dS m^{-1}. However, the salinity is washed off by heavy monsoon rains and the EC gets reduced to 4 to 6 dS m^{-1} making the soil favourable for cropping. In saline environment, plants take up excessive amounts of Na which affects crop growth and yield. Besides, deficit in rains during monsoon leads to regeneration of the inherent acidity and worsens the condition. Thus crop failure due to acidity and salinity become common in *Pokkali* system, especially in the changing climatic scenario.

Ameliorants containing sufficient amount of calcium inhibit the effect of soil acidity as well as soil salinity. With supplemental calcium in the

*Author for correspondences: Phone: 9446605795, Email: deepa.thomas@kau.in

rooting environment, it is expected that uptake of K can be improved and sodium accumulation reduced in plants. However in *Pokkali* soils, Na content in the plant tissues even exceeds the levels of the actual metabolic requirement, and turns harmful to growth. The resultant high ratio between Na and other cations like K, Ca and Mg within the plant becomes detrimental for the crop. Maintaining a low ratio of Na with other cations especially K, is necessary for realizing higher yields. As no response to soil application of nutrients is observed in *Pokkali* rice, foliar nutrition of K is expected to maintain nutritional balance within the plant. Hence the present study was proposed to narrow down the Na/K ratio in *Pokkali* rice by liming and foliar application of K.

The study was conducted during *kharif* season of 2018 -19 at Rice Research Station, Vyttila. VTL-8 was the variety used for the field experiment. The crop was sown during June and harvested in October with a total duration of 137 days. Field experiment was laid out in randomized block design with 3 replications and 10 treatments. Treatments included application of different levels of lime (500 and 1000 kg ha^{-1}) or dolomite (800 and 1600 kg ha^{-1}) alone, and these treatments along with foliar spray of sulphate of potash (SOP), 2% at 20 and 40 days after transplanting (DAT). These treatments were compared with foliar spray of SOP alone and a control (no amelioration, no foliar spray). Lime and dolomite were applied to the field before transplanting as per the treatments in technical programme. Foliar spray of SOP was done at 20 and 40 days after transplanting. Observations on different growth and yield attributes were recorded. Plant samples were collected at 20 days after transplanting (DAT), 40 DAT, flowering and at harvest, and analysed. The data recorded from various treatment plots were subjected to statistical analysis with the help of Web Agri Stat Package (WASP 2.0) developed by ICAR Central Coastal Agricultural Research Institute in Goa.

Results on growth parameters of rice indicated that there was considerable improvement in growth with soil amelioration and foliar nutrition with sulphate of potash. Even though there was significant variation among treatments, plant height did not show any specific trend in this variation. Application of lime @1000 kg ha^{-1} along with foliar nutrition with SOP produced more number of tillers per m^2 at harvest. A higher leaf area index was observed for treatments with higher doses of liming along with foliar spray of SOP (Table 1). Bohra and Doerffling (1993) reported that under saline conditions, potassium application enhanced the plant height, number of tillers and shoot dry weight. In addition to this, application of lime also significantly increased the plant height in a quadratic manner in tune with the results of Fageria and Knupp (2014).

Table 1. Effect of different levels of lime application and SOP foliar spray on growth and yield parameters in *Pokkali* rice

Treatment	Plant height (cm)	Number of tillers/m^2	Leaf area index	Number of panicles per m^2	Percentage offilled grains	Grain yield (kg ha^{-1})	B:C ratio
T_1 - Control	85.0	383.0	4.9	253.7	80.8	1495.0	1.11
T_2 - Lime @ 500 kg ha^{-1}	82.8	375.3	5.1	299.7	75.6	1407.0	0.97
T_3 - Lime @1000 kg ha^{-1}	83.8	424.0	4.2	332.0	78.8	1770.0	1.14
T_4 - Dolomite @ 800 kg ha^{-1}	86.6	384.7	4.7	346.3	84.7	1670.0	1.16
T_5 - Dolomite @1600 kg ha^{-1}	83.8	427.6	5.0	357.0	73.7	2360.0	1.53
T_6 - SOP 2% foliar spray	81.4	376.0	4.6	324.3	80.7	1975.0	1.39
T_7 -Lime @500 kg ha^{-1} +SOP 2% foliar spray	89.2	424.7	4.4	332.7	77.8	1461.0	0.96
T_8 - Lime @1000 kg ha^{-1} +SOP 2% foliar spray	87.1	458.0	5.7	428.0	89.4	2975.0	1.84
T_9 - Dolomite@ 800 kg ha^{-1} +SOP 2% foliar spray	88.0	361.0	4.3	305.3	84.3	1483.5	0.98
T_{10} - Dolomite @1600 kg ha^{-1} +SOP 2% foliar spray	86.8	437.7	6.3	381.0	86.5	2276.0	1.41
CD (0.05)	4.49	48.30	1.15	50.92	6.18	356.68	

A positive influence of various treatments could be seen on yield and yield attributes also. Treatment having the combination of lime application @1000 kg ha^{-1} and 2 per cent foliar spray of SOP recorded higher values for grain yield, percentage of filled grains and number of panicles per m^2 (Table 1). This might be due to the positive impact of lime in ameliorating the issues of salinity and acidity in *Pokkali* soil. In a study conducted to assess the ameliorating effect of different levels of lime, saw dust and gypsum in *Pokkali* soils, it was found that there was an enhancement in yield by 21 per cent with the application of lime @ 1000 kg ha^{-1} (Shylaraj et al*.,* 2013). Studies have also shown that foliar spray of KCl in rice generated a positive response in rice yield, which was almost double than that of untreated control (Nair et al., 1993). Ali et al. (2005) reported that application of potassium sulphate produced more tillers, straw and paddy yield.

The highest grain yield (2975 kg ha^{-1}) was obtained from the treatment with lime application @ 1000 kg ha^{-1} and 2 per cent SOP foliar spray. Application of dolomite @ 1600 kg ha^{-1} also resulted in a higher grain yield next to the best treatment. *Pokkali* soil, being deficient in Mg, responded well to the application of dolomite, which enhanced the total dry matter production. The results obtained were in accordance with the findings of Suriyagoda et al. (2017) who reported that enhanced shoot and root dry weight in rice with dolomite application was due to increased biomass of stems, dead leaves and grains. B:C ratio also was the highest for the treatment T_8 with lime @1000 kg ha^{-1}+ foliar spray of K at 20 and 40 DAT.

At 20 DAT, lime and dolomite application at higher doses resulted in significantly higher K content in plant. Towards maturity, higher potassium content was recorded in the treatment applied with lime @ 1000 kg ha^{-1} + SOP spray. Sodium content was higher for the control treatment during all stages of crop growth (Table 2). This indicated the positive influence of treatments in reducing the plant sodium content. During the critical flowering stage, the lowest sodium content was observed for T_8 [Lime @ 1000 kg ha^{-1} + K (2% spray) at 20 and 40 DAT] followed by dolomite application alone (800 kg ha^{-1} and 1600 kg ha^{-1}) or in combination with foliar spray of SOP. Foliar spray of SOP also exhibited some positive influence in reducing the deleterious effects of high sodium in plant. Under saline environment, high concentration of Na^+ and Cl^- ions might interfere with the phloem loading and uptake of nutrients from roots to shoot. But when nutrients were supplied through leaves, the nutrient elements entered the system through the leaves and restricted the inhibition imposed by these toxic ions and reduced the salinity induced nutrient deficiencies in plants (Sultana et al, 2001). From the results obtained, it was clear that at harvest stage sodium content was high in straw as compared to grain. The type of mechanism for alleviating the soil salinity stress in plants was compartmentalization (Munns, 2002).

Table 2. Effect of different levels of lime application and SOP foliar spray on K and Na content in *Pokkali* rice

Treatment	Potassium (%)					Sodium (%)				
	20 DAT	40 DAT	Flowering	Grain	Straw	20 DAT	40 DAT	Flowering	Grain	Straw
T_1 - Control	1.03	1.23	1.98	0.29	1.71	0.83	0.87	0.84	0.16	1.32
T_2 - Lime @ 500 kg ha^{-1}	1.12	1.23	2.07	0.31	1.73	0.92	0.81	0.70	0.16	0.94
T_3 - Lime @1000 kg ha^{-1}	1.21	1.30	2.08	0.31	2.00	0.73	0.80	0.68	0.15	1.12
T_4 - Dolomite @ 800 kg ha^{-1}	1.07	1.28	1.83	0.30	1.70	0.56	0.85	0.59	0.16	1.23
T_5 - Dolomite @1600 kg ha^{-1}	1.15	1.33	2.10	0.28	1.83	0.60	0.87	0.59	0.15	1.15
T_6 - SOP 2% foliar spray	1.09	1.36	1.89	0.30	2.08	0.70	0.78	0.64	0.14	1.26
T_7 - Lime @500 kg ha^{-1} +SOP 2% foliar spray	1.15	1.45	1.90	0.28	1.94	0.70	0.80	0.71	0.14	1.02
T_8 - Lime @1000 kg ha^{-1} +SOP 2% foliar spray	1.21	1.54	2.21	0.31	2.11	0.73	0.80	0.57	0.13	1.09
T_9 - Dolomite@ 800 kg ha^{-1} +SOP 2% foliar spray	1.07	1.37	1.99	0.29	1.94	0.72	0.86	0.71	0.13	1.15
T_{10} - Dolomite @1600 kg ha^{-1} +SOP 2% foliar spray	1.12	1.46	2.10	0.31	1.95	0.72	0.85	0.58	0.13	1.17
CD (0.05)	0.09	0.14	0.10	0.02	0.13	0.18	0.06	0.10	0.02	0.10

Table 3. Effect of different levels of lime application and SOP foliar spray on Na/K ratio in *Pokkali* rice

Treatment	Na/K ratio				
	20 DAT	40 DAT	Flowering	Grain	Straw
T_1 - Control	0.807	0.720	0.430	0.547	0.777
T_2 - Lime @ 500 kg ha^{-1}	0.823	0.663	0.333	0.503	0.543
T_3 - Lime @1000 kg ha^{-1}	0.603	0.620	0.327	0.493	0.560
T_4 - Dolomite @ 800 kg ha^{-1}	0.523	0.667	0.323	0.523	0.723
T_5 - Dolomite @1600 kg ha^{-1}	0.523	0.650	0.283	0.530	0.627
T_6 - SOP 2% foliar spray	0.640	0.573	0.333	0.473	0.603
T_7 - Lime @500 kg ha^{-1} +SOP 2% foliar spray	0.603	0.553	0.373	0.497	0.527
T_8 - Lime @1000 kg ha^{-1} +SOP 2% foliar spray	0.620	0.513	0.257	0.413	0.520
T_9 - Dolomite@ 800 kg ha^{-1} +SOP 2% foliar spray	0.673	0.623	0.357	0.437	0.593
T_{10} - Dolomite @1600 kg ha^{-1} +SOP 2% foliar spray	0.637	0.587	0.277	0.430	0.597
CD (0.05)	0.175	0.096	0.053	0.07	0.066

Plant nutrient ratios are considered as indicators of tolerance under saline environment, Na/K ratio being the most important one. From the results shown in Table 3, it was clear that control plants acquired higher Na/K ratio during all crop growth stages. Treatments T_8 (Lime @1000 kg ha^{-1} + SOP spray), T_{10} (Dolomite @ 1600 kg ha^{-1} + SOP spray) and T_5 (Dolomite @ 1600 kg ha^{-1}) registered significantly lower values compared to other treatments during the flowering stage. Zhang et al. (2010) observed that application of supplemental calcium had a role in mitigating the toxic effects of sodium in saline soils by the replacement of displaced Ca^{2+}, thereby regaining the cell wall stability and plasma membrane integrity, maintaining higher K/Na ratio in plant tissues. This led to enhanced salt tolerance in plants. Ashraf et al. (2017) reported that addition of K as potassium sulphate in cotton plant at different levels of salinity reduced the Na accumulation in plant tissues, increased shoot K^+, K^+: Na^+ ratio and Ca^{2+} and ultimately enhanced the yield attributes and fibre quality.

The correlation coefficients of yield and yield attributes with Na/K ratio at different stages (20, 40, flowering and harvest) are presented in Table 4. A perusal of the data showed that grain yield had significant positive correlation with number of panicles per m^2 (0.862**) and significant negative correlation with Na/K ratio at flowering (-0.816**). Na/K ratios at 40 DAT (-0.736*) and flowering (-0.903**) were found to be negatively correlated with number of panicles per m^2. Out of these, Na/K ratio at flowering was more negatively correlated with number of panicles per m^2, revealing the importance of Na/K ratio at flowering stage. So maintaining a low Na/K ratio at flowering could enhance the yield and productivity in *Pokkali* rice.

Table 4. Correlation analysis of Na/K ratio, yield and yield attributes

	Yield	Na/K at 20 DAT	Na/K at 40 DAT	Na/K at Flowering	Na/K ratio at harvest	Thousand grain weight	Grains per panicle	Percentage of filled grains	Number of panicles per m^2
Yield	1.000								
Na/K at 20 DAT	-0.427	1.000							
Na/K at 40 DAT	-0.571	0.365	1.000						
Na/K at Flowering	-0.816**	0.533	0.535	1.000					
Na/K ratio at harvest	-0.514	0.078	0.766**	0.543	1.000				
Thousand grain weight	0.611	-0.171	-0.488	-0.577	-0.598	1.000			
Grains per panicle	0.140	-0.565	-0.237	-0.277	-0.015	0.119	1.000		
Percentage of filled grains	-0.332	-0.151	-0.243	0.301	-0.217	-0.027	-0.251	1.000	
Number of panicles per m^2	0.862**	-0.616	-0.736*	-0.903**	-0.618	0.646*	0.203	-0.032	1.000

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