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Soil amelioration and foliar nutrition for ion homeostasis and nutrient uptake in Pokkali rice

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Abstract
Pokkali is a special rice farming system in coastal saline soils of Kerala. In these soils, higher sodium (Na) content and its interaction with other cations like potassium (K), calcium (Ca) and magnesium (Mg) within the plant become harmful for crop. Maintaining a low ratio of Na with other cations especially with K, is considered to be an yield determining and salt tolerance criterion in crops. There is a need to develop technologies in Pokkali rice for enhancing production and to have an edge in mitigating these stress conditions. A study was conducted at Rice Research Station, Vyttila with an objective to study the effect of the narrowing down of Na/K ratio in Pokkali rice by liming and foliar application of K. Treatments included soil application of different levels of lime (500 and 1000 kg/ha) or dolomite (800 and 1600 kg/ha) alone and these treatments followed by foliar spray of sulphate of potash (2% foliar spray at 20 and 40 days after transplanting). These treatments were compared with foliar spray of sulphate of potash alone and an absolute control (no amelioration, no foliar spray). The study showed that the sodium content in rice, Na/K ratio and Na/Ca ratio at flowering were negatively correlated with the grain yield. Among these ratios, higher Na/K ratio exhibited much more negative influence on the grain yield. A perusal of the data on correlation of Na/K ratio at different growth stages with yield also showed that treatments significantly influenced the plant Na/ K ratio at different stages of crop growth; Na/K ratio at flowering stage was found to be the most critical one. So maintaining a low Na/K ratio during the flowering stage benefitted the crop significantly. This indicated that amelioration and foliar spray of sulphate of potash in the field had significant influence in reducing the plant Na/ K ratio. Hence application of lime @1000 kg/ha and 2% foliar spray of sulphate of potash at 20 and 40 days after transplanting can be recommended for the increase in yield of Pokkali rice.

Keywords: Pokkali, foliar nutrition, ion homeostasis, salinity management

1. Introduction
Pokkali is a peculiar and sustainable 'rice farming' system in coastal saline soils of Kerala. Pokkali ecosystem has two phases - one a low saline phase (from June to October) during which salinity is partially washed out due to rains and salinity tolerant rice varieties are cultivated and secondly a high saline phase (November to May) during which prawns and other brackish water fishes are grown. Pokkali system is unique in the world and has received Geographic Indication Certificate and Plant Genome Saviour Community Award during 2010-11. Pokkali, the most saline tolerant rice variety of the world has proved its dominance as international donor of Saltol QTL as recognized by the International Rice Research Institute, Philippines.

Salinity, submergence and high inherent acidity are the major issues underlying this special system of rice cultivation. Liming is a most important strategy for reducing the soil acidity, by replacing the hydrogen ions with Ca^{2+} ions, thereby regaining the cell wall stability and plasma membrane integrity. This eventually leads to enhanced salt tolerance in plants. Besides, liming stimulates soil biological activity and increases the availability of primary and secondary nutrients to plants.

In saline environment, plants take up excess amounts of sodium which exhibits a significant negative correlation with the uptake of other nutrients like K^+, Ca^{2+} etc. The resultant high ratio between Na and other ions like K, Ca and Mg within the plant becomes detrimental for crop. Among these, Na/K ratio is the most reliable indicator of the level of salt tolerance in plants and maintaining a low ratio of Na with other ions especially with K is necessary for realizing higher yields. Foliar nutrition of potassium is expected to maintain nutritional balance within the plant. Usually potassium and sodium coexist on the soil exchange complex and soil solution. They exert antagonistic or synergistic effects on mutual absorption and translocation within plants, particularly under saline field conditions. Pokkali being naturally organic, potassium sulphate is an effective source of potassium for mitigating the adverse effect of sodium and thereby enhancing the crop yield under saline soils. Hence the objective of present study was to investigate the effect of liming and foliar nutrition of potassium on mineral nutrient concentrations, ion homeostasis and yield of Pokkali rice.

2. Materials and Methods

The experiment was conducted during 2018-19 at Rice Research Station, Vyttila which is the only institute which investigates the various aspects of the rice based farming system of the salinity prone coastal tracts in Kerala. Geographical location of the field is at 10^0 N latitude, 76^0 15^1 E longitude and at an altitude of 1.2 m above the mean sea level.

2.1 Soil and climate

Pokkali soils are is rich in organic matter, tidal ingression playing a major role in maintaining the nutrient status of the soil. These soils are inherently acidic and become acid saline due to sea water ingression. They are classified as clay loam in texture. The electrical conductivity (EC) of soils during the high saline phase (November - May) varies from 12 to 24 dS m^{-1} and average salt content reaches up to 20 mg kg^{-1}. During low saline phase (June - October) water becomes almost fresh, salt content reduces to traces and EC ranges between 4 and 8 dS m^{-1}.

The area of the experimental site enjoys a tropical humid climate. The mean annual rainfall of the area was 250 mm, the major part of which was received during the south west monsoon. The maximum day temperature varied from 28 °C to 40 °C and minimum temperature from 23 °C to 27 °C. The relative humidity was varied from 68 to 84% during the cropping season. The physico- chemical characteristics of soil in the experimental site are detailed in Table 1.

Table 1: Physico - chemical properties of soil

Particulars	Content	Method used
Coarse sand (%)	4.67	Robinson international pipette method (Piper, 1966) [13]
Fine sand (%)	21.76	
Silt (%)	19.63	
Clay (%)	50.76	
pH	4.22	Soil water suspension (1:2.5) read in a pH meter (Hesse, 1971) [7]
EC	0.96	Soil water suspension (1:2.5) read in a conductivity meter (Jackson, 1958) [8]
Organic carbon (%)	2.33	Walkley and Black method (Jackson, 1958) [8]
Available N (kg ha^{-1})	353.3	Alkaline permanganate method (Subbiah and Asija, 1956[) [16]
Available P (kg ha^{-1})	26.5	Bray-I extractant ascorbic acid reductant method (Watnabe and Olsen, 1965) [20]
Available K (kg ha^{-1})	368.8	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958) [8]
Available Ca (mg kg^{-1})	263.0	
Available Mg (mg kg^{-1})	44.0	Neutral normal ammonium acetate extract method with atomic absorption spectrophotometer (Jackson, 1958) [8]
Available S (mg kg^{-1})	38.5	Calcium chloride extraction and estimation by turbidimetry (Tabatabai,1982) [18]

2.2 Crop culture

VTL-8 was the variety used for the field experiment. Land preparation was initiated during April before the onset of monsoon. Bunds were strengthened and sluices were repaired for regulating the water level in the field. Water in the field was drained during low tide and shutters were placed preventing further entry of water. On dry field, mounds of $1m^2$ base and 0.5 m height were made to facilitate the washing down of salts during rains. With the onset of monsoon, dissolved salts from the surface of mounds were flushed out from the field. Mounds act as an elevated *in-situ* nursery which protects the rice seedlings from flash floods. Pre-germinated seeds were broadcasted on these mounds and were then plastered with soil to prevent the predation by birds. Mounds were dismantled 21 days after sowing and seedlings were uniformly transplanted in the field. Lime and dolomite were applied to the field before transplanting as per the treatments. Foliar spray of SOP was done at 20 and 40 days after transplanting. Plant samples were collected at 40 DAT, flowering and at harvest. Grain and straw were separately analysed as per Table 2 to know the degree of nutrient partitioning among them.

Table 2: Analytical methods used for plant analysis

Element	Method	Reference
Nitrogen	Micro Kjeldahl method	Piper, 1966 [13]
Phosphorus	Digestion of plant samples using diacid extract followed by colorimetric estimation in spectrophotometer by Vanadomolybdate yellow color method.	Piper, 1966 [13]
Potassium and Sodium	Digestion of plant samples using diacid extract followed by filtration and determined by flame photometer	Piper, 1966 [13]
Calcium and Magnesium	Determination using atomic absorption spectrophotometer	Piper, 1966 [13]
Sulphur	Turbidimetric method using spectrophotometer	Chesnin and Yein, 1951 [5]
Boron	Dry ashing of plant tissue followed by determination using Spectrophotometer	Gupta, 1972 [6]

The data recorded from various treatment plots were analysed with the help of software WASP 2.0 developed by ICAR-Central Coastal Agricultural Research Institute, Goa.

3. Results and Discussions

The results on growth parameters indicated that there was considerable improvement in growth with soil amelioration and foliar nutrition with sulphate of potash. The combination of lime @1000 kg ha^{-1} and K foliar nutrition produced taller plants with greater number of tillers per m^{2}and more leaf area at flowering (Table 3). Bohra and Doerffling (1993) [3] reported that under saline conditions potassium application enhanced the plant height, number of tillers and shoot dry weight. More number of panicles per m^2 and higher grain yield were recorded for the treatment lime @ 1000 kg ha^{-1} and 2 per cent foliar spray of sulphate of potash. Liming enhanced grains per panicle. The individual effect of dolomite on yield was higher than the individual effect of lime or foliar spray of K. The individual effect of foliar spray of K on yield was higher, but comparable with the individual application of lime @1000 kg ha^{-1}

Table 3: Effect of amelioration and foliar spray of SOP on growth and yield of Pokkali rice

Treatments	Plant height (cm) at flowering	Number of tillers/m^2 at flowering	Leaf area index at flowering	Number of panicles per m^2	Grains per panicle	Grain yield (kg ha^{-1})
T_1- Control	79.4^{bc}	320^{bc}	4.9^{bc}	254^{e}	72^{e}	1495.0^{ef}
T_2 - Lime 500	82.3^{abc}	257^{d}	5.1^{bc}	300de	78de	1407.0^{f}
T_3 - Lime 1000	79.9^{bc}	309^{bc}	4.2^{c}	332^{bcd}	98^{a}	1770.0^{de}
T_4 - Dolomite 800	83.5^{ab}	248^{d}	4.7^{bc}	346^{bcd}	78de	1670.0^{def}
T_5 - Dolomite 1600	82.1^{abc}	297^{cd}	5.0^{bc}	357^{bc}	98^{a}	2360.0^{b}
T_6 – SOP	82.8^{abc}	314^{bc}	4.6^{c}	324^{cd}	84^{cd}	1975.0^{cd}
T_7 - Lime 500 +SOP	85.1^{a}	359^{ab}	4.4^{c}	333^{bcd}	88^{c}	1461.0^{ef}
T_8 - Lime 1000 + SOP	84.5^{a}	377^{a}	5.7^{ab}	428^{a}	82^{cd}	2975.0^{a}
T_9 - Dolomite 800 + SOP	78.4^{c}	340^{abc}	4.3^{c}	305^{d}	89^{abc}	1483.5^{ef}
T_{10} - Dolomite 1600 + SOP	85.9^{a}	352^{ab}	6.3^{a}	381^{ab}	78de	2276.0^{bc}

3.1 Effect of treatments on plant nutrient content

Treatments showed significant effect on the nutrient content in the plant (Table 4). Liming stimulates soil biological activity and increases the availability of the primary and secondary nutrients to plants. At flowering, highest nitrogen and phosphorus content were observed in treatments with combination of lime or dolomite application and foliar spray of SOP at 20 and 40 DAT. This might have been due to the acceleration of additional P and K absorption facilitated by the calcium sufficiency in the soil (Kawasaki, 1995) [9]. Amelioration and foliar application of SOP resulted in enhanced K absorption also. At flowering, T_8 was followed by T_{10} during which T_3 and T_5 also were comparable.

As regards to calcium content at flowering, treatments T_3, T_5, T_8 and T_{10} (amelioration at 100% with or without foliar spray) were found to be having better content than others. Control treatment recorded the least calcium content in plant. Magnesium content also was enhanced by liming. At flowering, highest value was recorded for treatment T_8 [combination of Lime @ 1000 kg ha^{-1}and foliar spray of S0P at 20 and 40 DAT] and was on par with treatment T_3 (Lime @ 1000 kg ha^{-1}). The lowest was observed in treatment T_4 (0.184%).

Sodium content was higher for the control treatment. This indicated the positive influence of treatments in reducing the plant sodium content. In Pokkali soils, most important element which influences the uptake of other mineral nutrients is sodium. Its content in plant indirectly determines the growth and performance of Pokkali rice. All treatments could produce positive effect on minimizing the sodium content. At flowering, T_8 recorded least value followed by T_{10}, T_5 and T_4.

Studies in Pokkali soils reported that amelioration may increase Na content in the plant tissues even exceeding the levels of the actual metabolic requirement and turn harmful to growth (Sasidharan, 2004) [15]. 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 T_{10}, T_4 and T_5. Foliar spray of sulphate of potash also exhibited positive influence in reducing the deleterious effects of sodium in plant. Under saline environment, the toxic ions Na^+ and Cl^- might interfere with the phloem loading, uptake of nutrients from roots to shoot etc. But when nutrients were supplied through leaves, the nutrient elements might have entered the system through the leaves and restricted the inhibition put forward by these toxic ions and reduced the salinity induced nutrient deficiencies in plants (Sultana *et al.*, 2001) [17]

Table 4: Effect of amelioration and foliar spray of SOP on nutrient content (%) at flowering in Pokkali rice

Treatments	N	P	K	Ca	Mg	S	Na
T_1- Control	1.07^{d}	0.54^{bc}	1.98^{de}	0.68^{d}	0.23^{e}	0.34^{ab}	0.84^{a}
T_2 - Lime 500	1.30^{bcd}	0.49^{c}	2.07^{bcd}	0.84^{bc}	0.24^{d}	0.24^{cd}	0.70^{b}
T_3 - Lime 1000	1.30^{bcd}	0.56^{bc}	2.08^{bcd}	0.86^{abc}	0.31^{a}	0.37^{a}	0.68^{bc}
T_4 - Dolomite 800	1.50^{ab}	0.57^{bc}	1.83^{f}	0.75^{cd}	0.18^{f}	0.36^{ab}	0.59^{cd}
T_5 - Dolomite 1600	1.10^{d}	0.61^{b}	2.10^{b}	0.96^{a}	0.26^{c}	0.17^{d}	0.59^{cd}
T_6 – SOP	1.37^{abc}	0.50^{c}	1.89^{ef}	0.69^{d}	0.29^{b}	0.29^{bc}	0.64^{bcd}
T_7 - Lime 500 +SOP	1.13^{cd}	0.55^{bc}	1.90^{ef}	0.81^{bc}	0.27^{c}	0.33^{ab}	0.71^{b}
T_8 - Lime 1000 + SOP	1.57^{a}	0.80^{a}	2.21^{a}	0.87^{ab}	0.31^{a}	0.24^{cd}	0.57^{d}
T_9 - Dolomite 800 + SOP	1.07^{d}	0.57^{bc}	1.99^{cde}	0.83^{bc}	0.23^{e}	0.34^{ab}	0.71^{b}
T_{10} - Dolomite 1600 + SOP	1.23^{cd}	0.63^{b}	2.10^{b}	0.89^{ab}	0.24^{d}	0.37^{a}	0.58^{cd}

3.2 Productivity and nutrient interrelation

Na/K ratio is one of the yield determining criteria especially in saline soils. Treatments significantly influenced the plant Na/K ratio at different stages of plant growth (Table 5). As the crop growth progressed the Na/K ratio showed a decreasing trend up to flowering. Control treatment recorded highest ratio at all crop growth stages. Application of lime @ 1000 kg ha-1 or dolomite @ 1600 kg ha-1 + K (2% spray) at flowering and harvest stage could narrow down the Na/K ratio at flowering stage and thereby increase the yield significantly. Alias *et al* (2020) [1] has reported that grain yield and number of panicles had significant negative correlation with Na/K ratio at flowering and flowering stage is the most critical stage for maintaining a low Na/K ratio.

At harvest, the ratio was less in grains than in straw. Besides, it was clear that at harvest stage sodium content was high in straw as compared to grain sodium content. This might have been due to the plant mechanism for keeping safe the progeny for next generation.

This type of mechanism for alleviating the soil salinity stress in plants is compartmentalization. The result obtained here was in accordance with the findings of Reddy *et al*. (2017) [14]. He reported that salt tolerant varieties could maintain comparatively lower concentrations of salts in panicle and flag leaves. In the case of panicle, substantially lower salt concentration was found in grain as compared to rice husks and rachis. Sodium chloride was the most decisive salt that restricts the crop production in saline areas. Plant restricted the movement of these salts to young meristematic tissues and instead moved them to older leaves and leaf sheaths for alleviating the salinity damage to plants (Munns, 2002) [12]. Rice was also able to compartmentalize these toxic ions in older leaves and structural tissues. This enhanced the senescence of older leaves and maintained the younger leaves at low Na concentrations. The presence of large vacuole helped the older leaves to sequestrate higher concentrations of Na^+, Cl^- and NO^{3-} than young leaves (Wang *et al.*, 2012) [19].

Na/Ca ratio was higher than Na/K ratio at all stages and in grains. Na/Ca ratio also exhibited a trend similar to Na/K ratio as control treatment recorded higher values in all stages. At flowering, treatments T_5, T_8 and T_{10} recorded lowest values. Treatments T_7, T_8, T_9 and T_{10} recorded lowest values in grain also. In straw too, T_8 recorded the least value for Na/ Ca ratio. Treatments T_8 [Lime @ 1000 kg ha^{-1} + K (2% spray) at 20 DAT and 40 DAT] and T_{10} [Dolomite @1600 kg ha^{-1} + K (2% spray) at 20 DAT and 40 DAT] registered lower values for both ratios during the critical stage of flowering. Results on yield and nutrient content indicated that these ratios played a great role in maintaining high yield. Therefore, it was essential to maintain a high K/Na ratio in plant tissues for better tolerance to salt stress (Maathuis and Amtmann 1999) [11]. Zhang *et al*. (2010) [22] 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 the enhanced salt tolerance in plants. An experiment conducted by Wu and Wang (2012) [21] indicated that application of calcium at low saline conditions reduced the Na^+ accumulation in roots and increase the K^+ accumulation in shoots. However, there was no effect on sodium and potassium accumulation in plant tissues under high saline conditions. Therefore, it was suggested to apply Ca under low salinity for regulating the K/Na homeostasis in plants. Ashraf *et al*. (2017) [2] reported that addition of K as potassium sulfate nutrition 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.

Table 5: Effect of Effect of amelioration and foliar spray of SOP on Na/K and Na/Ca ratio in Pokkali rice

Treatments	Na/K ratio			Na/ Ca ratio		
	Flowering	Grain	Straw	flowering	Grain	Straw
T_1- Control	0.430^a	0.547^a	0.777^a	1.253^a	0.597^a	1.553^a
T_2 - Lime 500	0.333^{bc}	0.503^{abc}	0.543^{cd}	0.837^b	0.550^{abc}	1.247^{de}
T_3 - Lime 1000	0.327^{bcd}	0.493^{abcd}	0.560^{cd}	0.787^{bcd}	0.537^{bcd}	1.390^{bc}
T_4 - Dolomite 800	0.323^{bcd}	0.523^{ab}	0.723^a	0.790^{bc}	0.560^{ab}	1.413^b
T_5 - Dolomite 1600	0.283^{cde}	0.530^{ab}	0.627^b	0.617^d	0.533^{bcd}	1.320^{bcd}
T_6 – SOP	0.333^{bc}	0.473^{bcde}	0.603^{bc}	0.933^b	0.530^{bcd}	1.403^b
T_7 - Lime 500 +SOP	0.373^b	0.497^{abcd}	0.527^d	0.877^b	0.490^{cde}	1.273^{cde}
T_8 - Lime 1000 + SOP	0.257^e	0.413^e	0.520^d	0.653^{cd}	0.477^{de}	1.157^e
T_9 - Dolomite 800 + SOP	0.357^b	0.437^{cde}	0.593^{bc}	0.863^b	0.453^e	1.317^{bcd}
T_{10} - Dolomite 1600 + SOP	0.277^{de}	0.430^{de}	0.597^{bc}	0.653^{cd}	0.477^{de}	1.297^{bcd}
CD (0.05)	0.053	0.07	0.066	0.171	0.06	0.12

The correlation analysis of nutrient content during different growth stages (Table 6) showed that it was not the direct effect of plant nutrient content, but the effect of one element on the activity of other element which influenced the yield. Potassium and calcium by themselves had direct positive effects and sodium had direct negative effect, but more than that the ratio between Na and other cations like K and Ca influenced the crop yield significantly. Potassium (0.648*) and phosphorus (0.864**) content in rice were positively correlated with the grain yield. While, sodium content in rice, Na/K ratio
(-0.816**) and Na/Ca ratio (-0.640*) at flowering were negatively correlated with the grain yield. Among these ratios, higher Na/K ratio exhibited much more negative influence on the grain yield. And there existed a significantly positive correlation between Na/K ratio, Na/Ca ratio and sodium content in the plant. The significantly positive correlation between the calcium and potassium (0.716*) was found to be higher than the positive correlation between potassium and phosphorus (0.658*). Calcium content in rice had a significantly negative correlation with the Na/Ca ratio at flowering.

3.3 Effect of amelioration and foliar spray of SOP on nutrient uptake

Nitrogen uptake was highest for T_8 [Lime @1000 kg ha^{-1}+ K (2% spray) at 20 and 40 DAT] with 67 kg ha^{-1}. It is clear from the Table 7 that treatments T_9, T_6 and T_3 were on par with T_8. And the lowest was observed in the control. Significant difference was recorded in phosphorus content due to various treatments. Treatment T_8 recorded highest value (9.82 kg ha^{-1}) and was on par with treatments T_{10} and T_5. But in the case of potassium uptake, highest value was noted for the treatment T_{10} (combination of dolomite @1600 kg ha^{-1}and foliar spray of SOP at 20 and 40 DAT). And the lowest value was showed by the control treatment. Calcium uptake was high for treatment T_5 followed by T_{10} and were on par with treatments T_4, T_6, T_8 and T_9. On the other hand, uptake of magnesium, sulphur and sodium did not vary significantly among different treatments.

Nutrient uptake is the movement of nutrients from external environments such as soil or air in to plant. Soil application and foliar application of different nutrient sources had some positive influence on uptake of N, P, K and Calcium. Highest nitrogen uptake was observed for the treatment T_8 [Lime @ 1000 kg ha^{-1} + K (2% spray) at 20 and 40 DAT] with 67.07 kg ha^{-1}. Nutrients were absorbed from the root zone of crop in ionic forms, which was indirectly influenced by the soil acidity and nutrient concentration in the soil. Application of lime increased the soil pH and facilitated the uptake of more nitrogen by the crop (Kihanda *et al.,* 1999) [10]. Highest phosphorus uptake was observed for treatment T_8 followed by T_5 and T_{10}. In the case of potassium uptake also, these three treatments recorded the best results, which were on par with treatments T_3, T_6 and the above results are in agreement with the findings of Chang and Sung (2004) [4], who reported that by reducing the toxic effects of Al in soil, liming enhanced the uptake of P and K. Similar trend was seen in case of calcium also. Higher calcium uptake was observed for the treatments T_5 and T_{10} followed by T_8. The increased calcium content in the soil resulting from the lime application might have been the reason for its higher uptake from these treatments. Treatments did not show significant influence on the uptake of magnesium, sulphur and sodium.

4. Conclusions

Application of higher dose of lime or dolomite followed by foliar spray of SOP resulted in taller plants with more number of tillers, more number of panicles per m^2 and higher grain yield. Potassium and calcium by themselves had direct positive effects and sodium had direct negative effect, but more than that the ratio between Na and other cations like K and Ca influenced the crop yield significantly. Among these ratios, higher Na/K ratio exhibited more negative influence on the grain yield. Correlation of Na/K ratio at different growth stages with yield showed that Na/K ratio at the flowering stage was the most critical one. So narrowing the ratio at this stage was found to be critical. Application of lime @ 1000 kg ha^{-1} or dolomite @ 1600 kg ha^{-1} + K (2% spray) at 20 and 40 DAT could narrow down the Na/K ratio at flowering stage and thereby increase the yield significantly

Table 6: Correlation between plant nutrient content, Na/ K and Na/Ca ratios at flowering and grain yield in Pokkali rice

	Yield	Na/K ratio	Na/Ca ratio	N	P	K	Ca	Mg	S	Na
Yield	1.000									
Na/K	-0.816**	1.000								
Na/Ca	-0.640*	0.935**	1.000							
N	0.225	0.066	0.338	1.000						
P	0.864**	-0.665*	-0.566	0.245	1.000					
K	0.648*	-0.574	-0.492	0.001	0.658*	1.000				
Ca	0.482	-0.705*	-0.839**	-0.522	0.496	0.716*	1.000			
Mg	0.494	-0.331	-0.243	-0.021	0.327	0.494	0.253	1.000		
S	-0.449	0.416	0.368	0.116	-0.249	-0.435	-0.451	-0.275	1.000	
Na	-0.726*	0.943**	0.899**	0.061	-0.554	-0.276	-0.539	-0.191	0.302	1.000

Table 7: Effect of amelioration and foliar spray of SOP on nutrient uptake (kg ha^{-1}) in Pokkali rice

Treatments	N	P	K	Ca	Mg	S	Na
T_1- Control	33.64^{d}	4.43^{e}	39.16^{d}	21.19^{d}	6.85	6.62	29.08
T_2 - Lime 500	47.22^{bcd}	6.73^{cd}	57.64^{bcd}	27.25^{cd}	8.76	7.95	31.20
T_3 - Lime 1000	52.69^{abc}	6.05^{cde}	66.53^{abc}	29.60^{bcd}	6.58	6.72	36.91
T_4 - Dolomite 800	36.80^{cd}	7.52^{bcd}	57.07^{bcd}	31.45^{abc}	9.41	9.40	40.57
T_5 - Dolomite 1600	49.20^{bcd}	9.45^{ab}	76.38^{ab}	39.79^{a}	9.95	10.30	47.48
T_6 – SOP	56.29^{ab}	7.78^{bc}	67.52^{abc}	32.17^{abc}	10.19	8.24	40.25
T_7 - Lime 500 +SOP	47.44^{bcd}	5.67^{de}	51.87^{cd}	23.85^{cd}	8.13	6.44	27.13
T_8 - Lime 1000 + SOP	67.07^{a}	9.82^{a}	75.79^{ab}	37.59^{ab}	10.39	10.17	38.17
T_9 - Dolomite 800 + SOP	53.26^{abc}	7.17^{cd}	67.63^{abc}	32.65^{abc}	8.92	7.75	39.55
T_{10} - Dolomite 1600 + SOP	44.67^{bcd}	9.30^{ab}	79.01^{a}	39.59^{a}	9.92	8.29	46.30
CD (0.05)	17.55	2.00	19.46	8.82	NS	NS	NS

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