# Potassium Supplying Capacity of Some Lowland Rice Soils in the Mekong Delta

By Nguyen My Hoa, Upendra Singh and Henry P. Samonte

*The indigenous potassium (K) supplying power of most soils in the Mekong Delta is not sufficient to support the intensive cropping system there. Exchangeable K is a reliable index for measuring the amount of available K under very intensive cropping conditions.*

*Irrigated rice without K (left), and with K (right).*

Crops growing on recent alluvial soils in the Mekong Delta generally do not respond to K fertilizer (Xuan and Hiep, 1970; Ren and Hoa, 1993). These geologically young soils are derived from mica-rich (24 to 50 percent mica) sediments (Uehara et al., 1974) and contain a large proportion of illite in the clay fraction (50 percent illite, 33 percent kaolinite, and 16 percent smectite as reported by Brinkman et al., 1985), giving them good K-supplying capacity. The practice of growing two to three crops each year for more than 25 years, coupled with large applications of nitrogen (N) and phosphorus (P) fertilizers, and the removal of crop residues have decreased the concentration of available soil K to either critical or deficient levels in many regions. No K fertilizer or only small amounts (30 kg $K_2O$/ha/year) are normally applied to clay textured soils where two to three crops of rice are grown annually. Rice straw removal and burning to clear the land for the succeeding rice crop are common practices. The exceptions to this are saline-intruded soils, where only one rice crop is grown annually and its crop residue is soil incorporated, and sandy soils where farmers are aware of responses to K fertilizer and commonly apply between 30 and 90 kg $K_2O$/ha/year. Evaluating these lowland rice soils and the K supplying power of the various fractions is essential in determining future K requirements for Vietnam's 3 million ha rice bowl in the Mekong Delta.

Table 1. Chemical properties of the soils.

| Soil No. | EC mS/cm | pH $H_2O$ (1:2.5) | OM, % | CEC, cmol/kg | Exchangeable cations Ca | Mg | K | Na |
|---|---|---|---|---|---|---|---|---|
| | | | | | cmol/kg | | | |
| 1 | 0.77 | 4.35 | 3.78 | 20.76 | 5.14 | 6.98 | 0.30 | 1.51 |
| 2 | 0.35 | 5.07 | 7.80 | 23.40 | 9.53 | 7.41 | 0.31 | 0.82 |
| 3 | 0.15 | 5.03 | 3.51 | 17.70 | 8.23 | 2.40 | 0.25 | 0.27 |
| 4 | 0.46 | 4.78 | 4.20 | 23.97 | 9.66 | 8.35 | 0.20 | 0.85 |
| 5 | 0.18 | 5.14 | 2.92 | 16.77 | 8.99 | 2.69 | 0.21 | 0.37 |
| 6 | 2.26 | 4.74 | 1.79 | 20.13 | 4.29 | 10.14 | 1.11 | 4.35 |
| 7 | 0.68 | 3.67 | 11.9 | 15.42 | 2.20 | 1.38 | 0.13 | 0.45 |
| 8 | 0.22 | 4.46 | 4.40 | 12.99 | 2.63 | 1.31 | 0.08 | 0.49 |
| 9 | 0.20 | 6.93 | 1.51 | 6.00 | 2.42 | 0.42 | 0.10 | 0.28 |
| 10 | 0.38 | 5.72 | 0.48 | 3.06 | 0.72 | 0.20 | 0.04 | 0.10 |

Table 2. Total K, non-exchangeable K and exchangeable K of the soils used in the study.

| Soil No. | Total K % | Non-exchangeable K | Exchangeable K |
|---|---|---|---|
| | | cmol/kg | |
| 1 | 1.70 | 0.62 | 0.40 |
| 2 | 1.72 | 0.41 | 0.45 |
| 3 | 1.88 | 0.29 | 0.35 |
| 4 | 1.49 | 0.55 | 0.30 |
| 5 | 1.91 | 0.59 | 0.27 |
| 6 | 1.88 | 0.97 | 1.24 |
| 7 | 1.20 | 0.17 | 0.25 |
| 8 | 0.77 | 0.21 | 0.16 |
| 9 | 0.44 | 0.14 | 0.12 |
| 10 | 0.57 | 0.39 | 0.03 |

This study had two objectives:

1. To determine the K supplying capacity of the major rice producing soils in the Mekong Delta soils using $HClO_4$-HF acid (total K), boiling 1 N $HNO_3$ (non-exchangeable K), and $NH_4OAc$ pH 7 (exchangeable K) extractants.

2. To correlate K soil tests and crop response using a greenhouse experiment to exhaust the supply of K in soil.

Ten soils representing four major soil groups in the Mekong Delta were collected, analyzed, and classified according to the FAO-UNESCO classification system (Figure 1). The texture of recent alluvial soils (1-5), the saline-intruded soil (6), the acid sulfate soil (7), and the Plinthosol (8) were determined to contain up to 65 percent clay, 30 to 40 percent silt, and 2 to 11 percent sand. The Podsoluvisol (9) and the Arenosol (10) were sandy textured (89 to 93 percent). Their chemical characteristics are shown in Table 1. Table 2 describes the total K, non-exchangeable K, and available K contents of each soil.

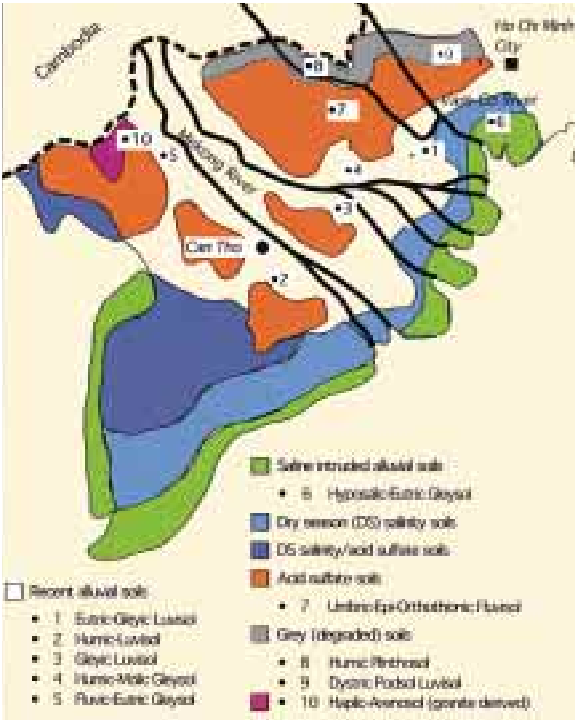
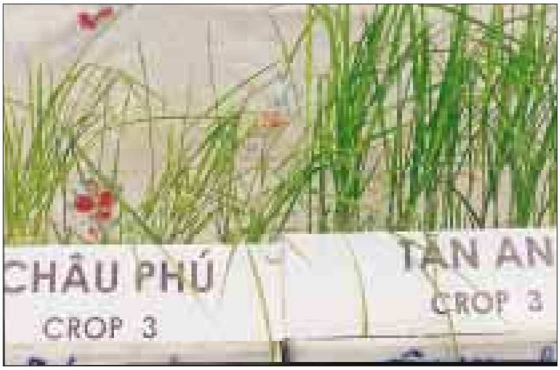


*Figure 1. Major soil groups in the Mekong Delta.*

In the greenhouse, pots were filled with one kg soil (2 mm sieve) and were planted with 50 rice plants in four successive crops. The pots were arranged in a completely randomized design with four replications. Fertilizer applications of 330 mg urea (46 percent N) and 260 mg diammonium phosphate (DAP, 18 percent N and 46 percent $P_2O_5$) were applied three times to each pot, but no K was added to the first three crops. In the fourth crop, 100 mg KCl (60 percent $K_2O$) was applied three times to all pots in addition to the N and P rates applied to the first three crops. Hoagland's micronutrient solution was applied to all pots once a week to all crops. Plants were harvested 5 weeks after sowing, and the amount of dry matter produced was recorded. Plant samples from each crop were analyzed for K concentration. Total K uptake in each crop was calculated. Soil samples were taken after the second crop for analysis of exchangeable K.

## Dry Matter Yield, K Concentration, and K Uptake of Rice Plants

Dry matter yields are shown in Table 3. First crop yields grown on the recent alluvial soils were the largest among the 10 soils under evaluation, and yields declined with each successive crop until K was applied to the fourth crop. Growth was severely affected by salinity in the saline-intruded soil and by acute K deficiency in the Arenosol. Plant K concentration shown in Figure 2 was above the critical level of 1 percent (De Datta, 1987) in plants grown in the saline-intruded soil and in the Humic Luvisol where K uptake and soil exchangeable K concentrations were also greatest. In plants grown on the other recent alluvial soils, leaf K concentrations ranged from 0.48 to 0.91 percent.



*Plant growth during the second exhaustive crop in the Fluvic-Eutric Gleysol (No. 5, at left) and the Eutric-Gleyic Luvisol (No. 1) of the recent alluvial soil group.*

Differences in soil K supply growth among the alluvial soils, induced by stage of mineral weathering and amount of K supplied by irrigation water, resulted in significant differences in second crop plant growth. The highest dry matter yield among the recent alluvial soil group occurred with the Eutric-Gleyic Luvisol. The most severe K deficiency symptoms (yellowing of leaf, distal tip turned, desiccated, and folded leaves) were observed 3 weeks after sowing in the Fluvic-Eutric Gleysol. Potassium deficiencies were evident on plants grown in all soils, except the Humic Luvisol and saline-intruded soils, which have the greatest K supplying power.

The largest dry matter yield, leaf K concentration, and K uptake occurred with the K-rich saline-intruded soil and was the result of leaching of free salts by rainwater. Dry matter yields were smallest in the acid sulfate and the grey degraded soils where exchangeable K concentration was low. Exchangeable K concentrations in soils decreased to 45 to 66 percent after two exhaustive crops (Figure 2). Potassium deficiency symptoms in rice were detected in all except two soils during the third crop sequence and dry matter yields were small. The exception was the saline-intruded soil where leaf K concentration was maintained above 1 percent and K uptake remained adequate. Potassium uptake from all the other soils was inadequate, indicating that the indigenous K supplying power of each soil is insufficient to support the intensive cropping system used by farmers in the Mekong Delta.

Potassium application to the fourth crop produced a large K response in all soils, causing leaf K concentration to be greater than 1 percent (Table 4) and dry matter yields greater than 6 g/pot (Table 3).

Table 3. Dry matter yield of three consecutive exhausting rice crops (g/pot) and the fourth K-fertilized crop.

| Soil No. | Crop 1 -K | Crop 2 -K | Crop 3 -K | Crop 4 +K |
|---|---|---|---|---|
| 1 | 11.68 bc | 9.35b | 3.31b | 10.17b |
| 2 | 13.40a | 7.88c | 2.31c | 10.24b |
| 3 | 12.46ab | 4.89d | 1.25de | 9.81b |
| 4 | 12.69ab | 5.06d | 1.65d | 8.16c |
| 5 | 13.49a | 3.26e | 1.18de | 10.16b |
| 6 | 4.32f | 10.87a | 12.40a | 12.52a |
| 7 | 9.49e | 3.12e | 0.74e | 7.87c |
| 8 | 10.95cd | 2.91e | 0.93e | 10.22b |
| 9 | 9.98de | 1.19f | +/ | 6.53cd |
| 10 | 2.34g | 1.02++/ | +/ | 6.03d |

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

+/ Because of micronutrient problem in the first planting, tests are delayed one crop for correction of the problem. Therefore the third crop of this soil is skipped for the fourth K-fertilized crop.

++/ Replication was incomplete, therefore statistic analysis was not done.

## Potassium Supplying Power of the Soil

This study showed that, although soil exchangeable K concentration was greater than the critical amount of 0.21 cmol/kg, K fertilizer and proper rice straw and manure management are required in order to preserve soil K fertility in intensively cropped recent alluvial soils. Without proper management, the removal of large amounts of K with each of the two to three crops per year may cause a reduction in non-exchangeable K, decomposition of K-bearing clay minerals, and K fixation which is then only overcome by very large K applications (Tributh, 1987). Potash is required in the acid sulfate soils and the grey (degraded) soils of the Mekong Delta where K supplying power was found to be insufficient to support more than one rice crop.

The saline-intruded soils of the Delta (at least where only one crop per year is grown and straw is recycled) have the largest potential indigenous soil K supplying power as soil K supply was maintained over three consecutive exhaustive crops of rice. However, a response to the large indigenous K supply is only available after desalination. Total K uptake after exhaustive cropping provides an indication of the K supplying power of the soil (Gholston and Hoover, 1948) although plants may not respond to K application in the field despite responses found with the more intensive glasshouse experiments (Ren and Hoa, 1993).

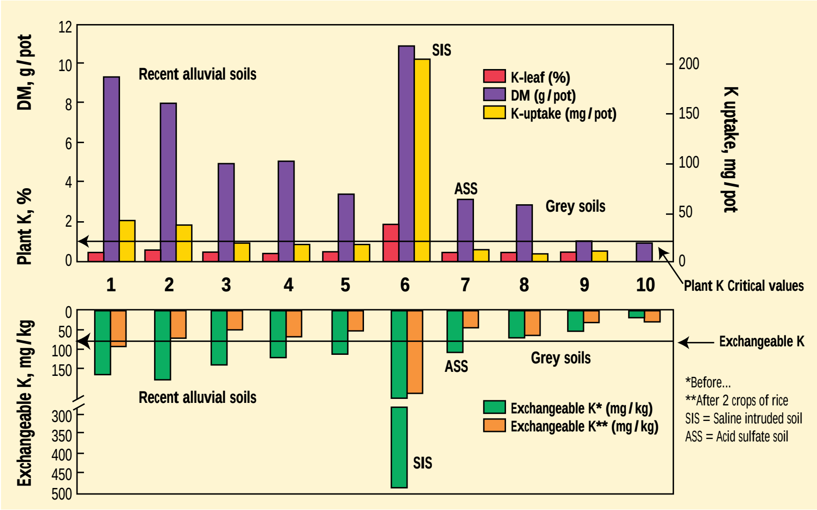


*Figure 2. Plant K concentration, dry matter yield, and K uptake of rice grown without K fertilizer in 10 selected soils of the Mekong Delta in Vietnam and exchangeable K in these soils before and after two crops. Results from the second of two consecutive exhaustive rice crops grown in pots (1 kg soil, 50 rice plants per pot).*

## Correlation Between Amount of K Extracted by Chemical Methods and Amount Extracted by two Successive Exhaustive Crops

Exchangeable K, non-exchangeable K, total K extracted with $HNO_3$ (exchangeable K + non-exchangeable K), and total K showed no correlation with K released from non-exchangeable forms by soils. There was, however, a highly significant correlation between total K uptake and the amount of exchangeable K before cropping, non-exchangeable K, and total K removed in two crops (r = 0.981**, 0.806**, 0.945**, respectively). The correlation coefficient of the relationship between exchangeable K and K uptake was slightly lower when data from the saline-intruded soil were excluded, but remained highly significant (P<0.01). Non-exchangeable K was not correlated with K uptake when data from the saline intruded soils were excluded.

Table 4. Potassium concentration of rice plants (% K) in three consecutive exhausting crops without K application and the fourth K-fertilized crop.

| Soil No. | Crop 1 -K | Crop 2 -K | Crop 3 -K | Crop 4 +K |
|---|---|---|---|---|
| 1 | 0.75d | 0.45c | 0.38c | 1.37c |
| 2 | 1.07b | 0.46c | 0.35c | 1.33c |
| 3 | 0.91c | 0.39c | 0.49bc | 1.40bc |
| 4 | 0.54f | 0.41c | 0.48bc | 1.64abc |
| 5 | 0.74d | 0.46c | 0.55b | 1.39bc |
| 6 | 2.89a | 1.90a | 1.63a | 1.74ab |
| 7 | 0.68b | 0.45c | 0.46bc | 1.68ab |
| 8 | 0.51f | 0.44c | 0.55b | 1.38c |
| 9 | 0.51 | 0.62b | +/ | 1.68abc |
| 10 | 0.48f | – | +/ | 1.85a |

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

+/ Because of micronutrient problem in the first planting, tests are delayed one crop for correction of the problem. Therefore the third crop of this soil is skipped for the fourth K-fertilized crop.

## Conclusions

Only marginal to adequate concentrations of exchangeable K were found in the recently formed alluvial soils of Vietnam's Mekong Delta. Their K supplying power appears to be related to weathering stage and to K supply in sediments and irrigation water. Potash fertilization on these soils is required to replace nutrients removed in grain and straw, to avoid further deterioration of soil K fertility status, and to increase productivity of high quality rice. Potash must be applied to acid sulfate soils, where exchangeable K is insufficient to support the high yields required by farmers, and to exchangeable-K deficient grey soils. Among the ten representative soils studied, only the saline-intruded soil did not require the addition of fertilizer K after three consecutive and exhaustive rice crops.

Exchangeable K was determined to be a reliable index for measuring the amount of available K under very intensive cropping conditions. Non-exchangeable K, measured by difference, was not reliable for estimating K release to the crops. BCI

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*Rice harvest in the Mekong Delta.*

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# Brazil: Fertility Management for Sustainable Cropping on an Oxisol of the Central Amazon

Researchers established an experiment to determine depletion patterns of soil nutrients, along with aglime and fertilizer requirements, for continuous cultivation after slash and burn clearing. Yield responses were evaluated over an eight-year period and involving 17 crops (including rice, soybeans, cowpea, and corn).

In the absence of fertilizer and aglime, soil nutrient levels dropped, soils became more acidic, and percent aluminum (Al) saturation increased. Mean crop yields with aglime and fertilizer application based on soil tests were 4.1 t/ha/yr compared to 0.2 t/ha/yr for check plots. Total grain yields obtained during eight years of proper soil fertility management were 24 times greater than those under shifting cultivation practices. BCI

*Source: Cravo, M.S. and T.J. Smyth. 1997. R. bras. Ci. Solo, Vicosa, 21: 607-616.*