Long-Term Phosphorus and Potassium Strategies in Irrigated Rice

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The site-specific nutrient management (SSNM) approach for rice provides sufficiently robust estimates of long-term fertilizer phosphorus (P) and potassium (K) requirements to avoid nutrient depletion. Additional information from long-term experiments may be required to fine-tune fertilizer P and K recommendations developed on-farm.

Management of soil P and K is receiving greater attention in intensive, irrigated lowland rice systems of Asia because of concerns that fertilizer P and K rates are not optimally adjusted to long-term needs. Breeding offers limited opportunities to change the plant nutrient requirements or uptake efficiencies so that long-term management strategies must focus on overcoming immediate nutrient deficiencies and maintaining adequate nutrient balances in the topsoil layer. Current fertilizer P and K strategies in Asia are still mostly based on soil tests that have shown little correlation with the effective nutrient supply to the irrigated rice crop (Dobermann et al., 2003).

In this rice plot in the Philippines, severe K deficiency symptoms were observed where only N and P were applied.

SSNM allows effective management of indigenous P and K supplies by estimating fertilizer requirements based on yield level, yield response to fertilizer P and K application, and a nutrient balance model (Fairhurst and Witt, 2002; Witt et al., 2002). In that approach, fertilizer P and K maintenance rates are commonly developed based on only 2 seasons of on-farm experiments, which may be insufficient to develop long-term strategies. In this paper, we evaluate SSNM strategies to prevent soil nutrient depletion using data from five long-term experiments established between 1968 and 1995 in China, India, Indonesia, the Philippines, and Vietnam.

In the SSNM approach, fertilizer P and K rates are based on the yield difference between treatments with full fertilizer use of N, P, and K (NPK) and omission plots that receive all nutrients except for the omitted (0P, 0K). Recommended fertilizer rates are provided in simple charts (see example in **Table 1**). The NPK, 0P, and 0K treatments were also included in five long-term experiments with two rice crops per year, and the accumulated yield difference between NPK and omission plots for a period of up to 15 seasons are plotted in **Figure 1**. There were substantial differences in short- and long-term yield responses to fertilizer P and K

Table 1. Maintenance fertilizer P_2O_5 rates (kg/ha) depending on yield in 0P plots and yield goal (adapted from Fairhurst and Witt, 2002).

Yield in 0-P plots, t/ha	Yield goal, t/ha 4	5	6	7	8
3	20	40	60	*	*
4	15	25	40	60	*
5	0	20	30	40	60
6	0	0	25	35	45
7	0	0	0	30	40
8	0	0	0	0	35

*A lower yield goal is recommended when the required yield increase exceeds 3 t/ha.

application among sites. Yields were not affected by K application in India or P application in China in the first 2 seasons, and initial yield responses to fertilizer application were generally small except for Vietnam (P) and China (K). However, yield responses developed within a few seasons at all sites except for K application at Omon in the Mekong River Delta of Vietnam, where annual flooding supplies a large K load through sedimentation. Yield responses developed linearly except for China, where yield responses to P but not K application developed exponentially within 8 seasons or 4 years. Long-term fertilizer requirements would generally be underestimated, if fertilizer requirements were based only on short-term yield responses without considering nutrient removal with grain and straw and the overall input-output balance.

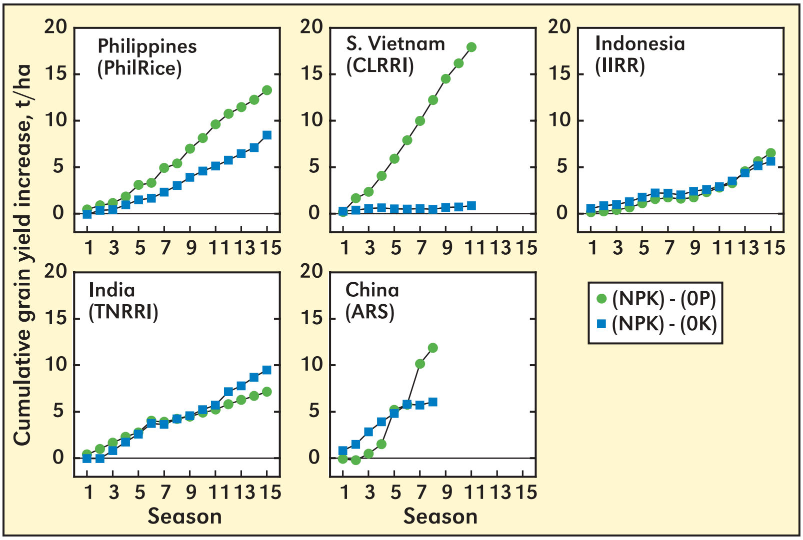

Figure 1. Cumulative grain yield increase in fully fertilized plots (NPK) over plots without fertilizer P (0P) and K (0K) application in long-term experiments at five sites in Asia, 1995-2002. PhilRice = Philippine Rice Research Institute, Muñoz, Philippines; CLRRI = Cuu Long Rice Research Institute, Omon, Vietnam; IIRR = Indonesian Institute for Rice Research, Sukamandi, Indonesia; TNRRI = Tamil Nadu Rice Research Institute (TNRRI), Tamil Nadu, India; ARS = Agricultural Research Station, Zhejiang, China.

In the absence of a yield response to fertilizer P and K application, SSNM recommends fertilizer P and K maintenance rates that are calculated based on a nutrient input-output model (Witt and Dobermann, 2004). Higher maintenance rates are suggested for higher yield levels because of a greater nutrient removal with grain and straw after harvest (see example in **Table 1**). Since initial yield responses appear to be generally small based on the presented data from long-term experiments, fertilizer requirements with SSNM may, to a larger extent, follow maintenance strategies. At issue is whether SSNM recommendations would need to be adjusted, if yield responses to fertilizer P and K application were evaluated for longer periods. **Table 2** shows fertilizer requirements calculated with SSNM based on data from 2 and 8 cropping seasons in the long-term experiments. Note that the actual fertilizer P and K rates were several times higher than the recommended rates with SSNM. High fertilizer P and K rates in long-term experiments are usually chosen to ensure that these nutrients are not limiting.

Considering 2 seasons of data, recommended fertilizer rates ranged from 21 to 32 kg P_2O_5/ha and from 20 to 48 kg K_2O/ha. Suggested rates were highest where both yield and yield responses to fertilizer application were high (Philippines, India, China). Fertilizer rates changed at some, but not all, sites when 8 instead of 2 seasons of data were considered in the calculation of fertilizer rates. Fertilizer rates needed little adjustment at sites where yield responses developed steadily and yields in NPK treatments remained more or less constant (e.g., Philippines). Adjustments in fertilizer rates were needed where yield levels in the first

Table 2. Average fertilizer rates and fertilizer requirements with SSNM (Fairhurst and Witt, 2002) based on the average yield increase (response) in N, P, and K fertilized plots (NPK) over plots without fertilizer P (0P) and K (0K) application during 2 and 8 cropping seasons in five long-term experiments in Asia.

Parameter	Unit	Sites: Philippines (PhilRice)	Vietnam (CLRRI)	Indonesia (IIRR)	India (TNRRI)	China (ARS)
		Fertilizer rates				
Starting year		1968	1995	1995	1995	1997
Fertilizer P_2O_5	kg/ha	60	57	57	57	57
Fertilizer K_2O	kg/ha	60	90	120	120	120
		Short-term fertilizer requirements				
Number of seasons		2	2	2	2	2
Grain yield (NPK)	t/ha	6.3	5.0	5.2	7.0	6.0
Yield response to P	t/ha	0.5	0.8	0.1	0.5	0.0
Yield response to K	t/ha	0.2	0.2	0.4	0.0	0.7
Fertilizer P_2O_5	kg/ha	28	23	21	32	24
Fertilizer K_2O	kg/ha	40	20	28	48	44
		Long-term fertilizer requirements				
Number of seasons		8	8	8	8	8
Grain yield (NPK)	t/ha	6.0	4.7	6.0	6.3	5.6
Yield response to P	t/ha	0.7	1.5	0.2	0.5	1.5
Yield response to K	t/ha	0.4	0.1	0.3	0.5	0.8
Fertilizer P_2O_5	kg/ha	27	30	25	28	29
Fertilizer K_2O	kg/ha	38	13	37	45	38

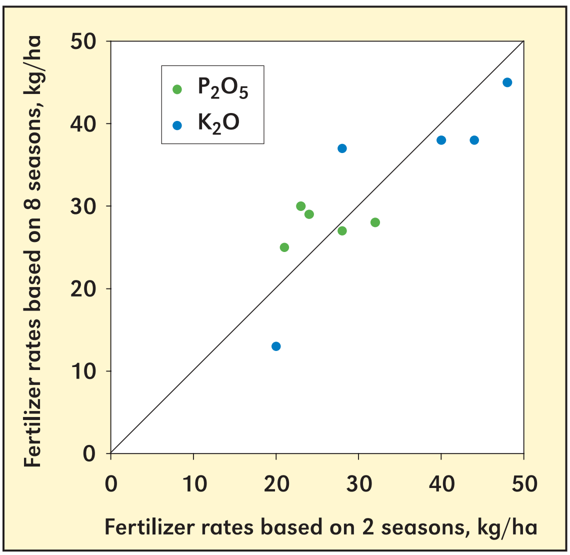

Figure 2. Fertilizer P_2O_5 and K_2O requirements with SSNM (Fairhurst and Witt, 2002) based on 2 and 8 seasons of data in long-term experiments at five sites in Asia, 1968-2002.

year were not representative for a longer time period, like in Indonesia, where yields increased with time. Adjustments were also needed where average yield responses to fertilizer application were either lacking or very strong over the 4-year period. A lacking yield response over a long period indicates a strong soil nutrient supplying power, while a strong yield response developed within a few seasons is a sign of a low soil buffering capacity to nutrient depletion. For example, 4 years of data from Omon revealed greater P, but lower K requirements compared to the rates calculated after one year. Despite these adjustments, the initial estimates of fertilizer requirements showed a good congruence with the fertilizer rates that were based on several seasons of data (**Figure 2**).

We therefore conclude that the SSNM approach would not have to be modified and that 2 seasons of data provide a first, sufficiently robust estimate of fertilizer P and K requirements. However, omission plots embedded in farmers' fields should be continued for several seasons at the same location, if data from long-term experiments are not available to identify the response pattern that develops over time and fine-tune SSNM recommendations.

In the last 4 years, the SSNM approach was disseminated with the involvement of more than 1,000 farmers in extension-led demonstration trials in Asia. The SSNM strategies were also incorporated into national initiatives in

Bangladesh, India, Indonesia, Myanmar, and Vietnam. BC

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The highest shoot and clove yields were obtained with 300-90-300 kg/ha at Shuikou. The two sites at Xin'an had much higher yield potential and achieved much higher relative yields under all treatments. Both sites at Xin'an suggest a potential for even higher yields given the good performance of the highest N/highest K combination, which produced very large yields and profits.

The economics of garlic production were greatly improved with addition of 150 kg K_2O/ha, at both N rates. However, the data clearly show that 300 kg K_2O/ha applied with N at rates of 300 to 375 kg/ha, regardless of site, provide the best return to farmers.

The effects of widespread adoption of balanced fertilization in garlic production systems in Southeast China could have immense economic impact. **Results point to consistently large and profitable responses to rational NPK rates and no doubt enhance this production system in the eyes of farmers searching for viable cash cropping options.** BC

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