Diagnosing variable nutrient deficiencies in rainfed lowland rice using strip trials

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Abstract

A farming systems project conducted in the Philippine province of Antique in the mid 1980s tested the yield responses of rainfed lowland rice to nutrients in 132 replicated experiments on farmers' fields. For first crops, the percentage of fields showing profitable responses to nutrients were: N, 86%; P, 52%; K, 67%; S, 53%; Zn, 70%. The recommended NPK application was profitable on 76% of fields. At the time, farmers applied the optimum rates of N, but almost none of the other nutrients, apparently because the responses were unreliable. Soil tests did not reliably identify the responsive fields and single-element fertilizer could not be obtained locally for field experiments. At the time, the project recommended a system in which small amounts of nutrients are applied in strips to help farmers in identifying deficient fields, but this suggestion was not followed up. The project area was revisited in 2001. Mean rice yields had hardly changed since the mid 1980s. Farmer co-operators from the previous project had adopted some of the recommendation for P, K and S, but not for Zn, which was still unobtainable locally. Fertilizer resellers reported little change in the fertilizer mix since the mid 1980s - optimum N but almost no P, K or Zn. These results support increasing evidence of that nutrients other than N are deficient in rice growing in many parts of Asia. The most promising approach to support farmers' decisions about fertilizer is a system of strip trials, largely conducted by farmers on their own fields, with support from the fertilizer industry.

Media summary

Deficiencies of phosphorus, potassium, sulfur and zinc limit rice yield in Asia, but are variable and difficult to diagnose. 'Strip trials' could identify deficient fields.

Key Words

rice, fertiliser, phosphorus, potassium, sulfur, zinc, strip trials

Introduction

From 1984 to 1986, a farming systems research project was conducted in the central Philippine province of Antique, called Pharlap (Philippine-Australian Rainfed Lowland Antique Project). The project was conducted by CSIRO Australia and the Philippine Department of Agriculture, with support from the Australian Centre for International Agricultural Research (Tasic et al. 1987; Menz 1989; Angus et al.1990). In this project 132 replicated field experiments were conducted on farmers' fields in three municipalities, over two years and in two seasons per year. Each experiment measured rice yield responses to N, P, and K. A smaller number of experiments measured responses to S and Zn (Table 1). The project showed that applications of N fertiliser were reliable and profitable and that, on average, there were large rice-yield responses to P, K, S and Zn. However, the yield responses to these nutrients were so variable between fields that it was difficult to predict whether there would be a profitable response on a particular field.

Table 1. Profitability of nutrients calculated from costs and returns of additional rice in the

Pharlap project, 1984-86. Numbers of observations are in brackets.

Input	Percentage of farm fields showing profitable* responses to inputs	
	First crops (85)	Second crops (47)
Recommended NPK 70/30/30'	76	62
First 35 kg N ha^{-1}	87	53
Second 35 kg N ha^{-1}	57	51
Phosphorus (13 kg P ha^{-1})	52	43
Potassium (28 kg K ha^{-1})	67	72
Sulfur	53 (15)	44 (9)
Zinc	70 (10)	83 (24)

*Additional returns > twice additional costs

The yield responses were unrelated to soil tests of organic matter, P and K and to the water status of the fields, which were almost all well flooded. P-only and K-only fertilizers were unavailable so it was impossible to diagnose deficiencies from field experiments. The reason for the variability is unknown but we speculated that there was transfer of nutrients by tethered livestock from outlying fields during the day to fields near the farmhouse at night.

A survey showed that farmers applied close to the recommended rate of N fertilizer, but little of the other nutrients. Fertilizer containing Zn was almost unobtainable in the province. This imbalance of fertilizer use is shown in Figure 1 as the percentages of N, P and K applied. Lowland farmers in Antique applied the most skewed distribution of nutrients among the points in Figure 1, but in Asia in general, and the Philippines in particular, relatively more N and less P and K is applied than in the world as a whole.

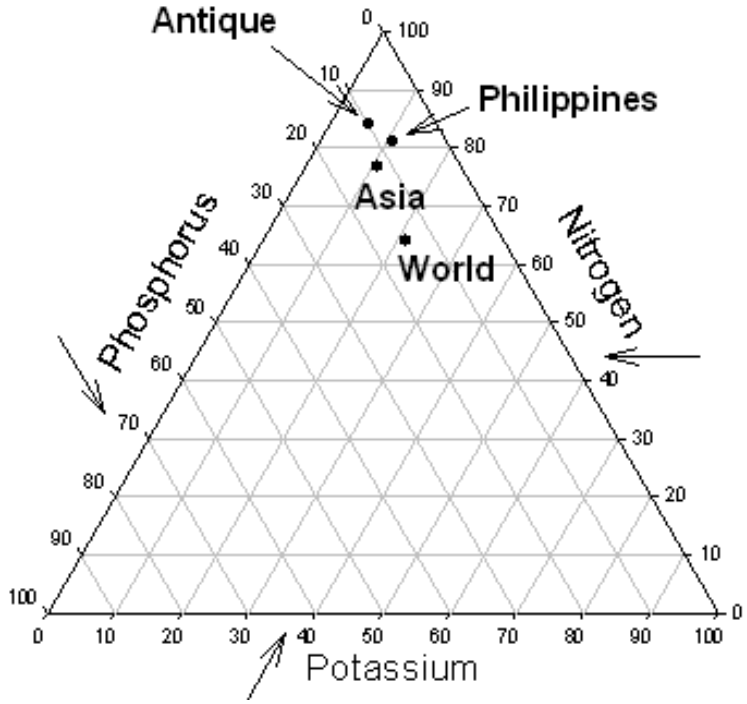

Figure 1. Percentage weights of N, P and K in fertiliser applied to rainfed lowland rice in Antique, compared with fertilizer use in the Philippines, Asia and the World.

The recommendation of the project was that a new system was needed so that farmers could decide for themselves which nutrients were needed on their fields. The system proposed was a large number of 'strip trials' set up by farmers and/or extension workers. They would apply a strip of single-element fertilizer on part of a rice field and observe or measure the yield response. The research at the time estimated that yields could be increased by about 25% by improved strategies for supplying these nutrients. No such system was tested after the conclusion of the project.

Confirmation of variable nutrient deficiencies

About 10 years after publication of these results, IRRI scientists confirmed variable yield responses of rice to P and K over many countries (Dobermann et al. 1998; Witt et al. 1999). However, while our recommendation was for strip trials, the IRRI conclusion was that better soil tests and computer-based decision support systems should be developed to predict nutrient responses. This proposal seems difficult to justify for resource-poor farming systems. For example, how could a soil test costing about $10-20 be justified for a typical lowland field with an area of one third of a hectare producing about $200 worth of rice and a gross margin of perhaps $40-50? How could information from a computer-based system be conveyed to farmers?

The problem of spatial variability of crop yields and nutrient responses is generally better recognized now than 15 years ago. During the 1990s, the science of Precision Agriculture has developed for mechanized farming. Precision Agriculture recognizes and attempts to cope with spatial variability rather than assuming constant conditions within a field. The typical scale of variability is similar to the size of a lowland rice field, but to our knowledge, there has been no attempt to encourage farmers to manage each field individually rather than on the basis or blanket recommendations.

The situation in 2001

In 2001, the former project team assessed the outcome of the project by asking farmers and fertiliser dealers about the mixture of nutrients applied to rice. We contacted 8 of the 58 farmer co-operators who reported fertiliser use in bags per hectare, which is presented as nutrient use in Table 2. Fertiliser dealers were approached and asked to estimate the number of bags of each type of fertiliser sold during the peak season, which is normally in the May-July period. Their data are also presented as nutrient use in Table 2 but are presented as the percentage of each nutrient because the crop area is unknown. No data on S were collected in the Pharlap project but it is likely that some S was applied in ammonium sulfate at that time, so the percentages of the other nutrients may be overestimated. The amount of data collected in 2001 is probably too small to be conclusive, but it does suggest that some of the former Pharlap cooperators do use relatively more K than formerly and also more than their current neighbours. In view of the small sample size of former Pharlap cooperators there is a need to confirm their more balanced fertiliser use.

Table 2. Macronutrients applied to lowland rice.

	N	P	K	S
Weight of nutrients (kg/ha)				
8 Pharlap farmer cooperators, 2001	50	7	11	21
Antique farmers, 1980-85[1]	67	6	2.4	n.a.
Philippine average[2]	49	5	6	12
Percentage of nutrients (total=100)				
Pharlap farm survey 1984-86	89	8	3	n.a.
Philippine average[2]	68	7	9	16
8 Pharlap farmer cooperators, 2001	56	7	13	23
7 Antique dealer's sales, 2001	67	8	5	20
Optimum for Antique rainfed rice, based on Pharlap	55	12	27	6
Philippine recommendations for lowland rainfed rice	61	13	25	n.a.

[1] Tasic et al. (1987)
[2] Philrice (1998), for rainfed lowland rice, mean for 1988-1995

Discussion

The Pharlap project showed that the long-standing Philippine recommended mix of N, P and K for rainfed lowland rice is, on average, fully justified in Antique, but as shown in Table 1, it is risky to follow P and K for a particular field . While the recommended rate of N is generally adopted in Antique, the recommendations for P, K, and Zn are not. The statistical data for the Philippines and Asia as a whole suggest that imbalanced nutrient supply is widespread.

Why have fertilizers containing P, K and Zn been so poorly adopted by farmers in Antique? We suggest 3 possible reasons. One is that responses were so variable that farmers are not confident of a profit. While this explains the P and K results, it does not explain the poor adoption or availability of Zn, which gave relatively reliable yield responses. Another possible reason is that P, K and Zn do not produce rapid growth responses like N, even if the visible response to N does not appear in yield. Finally there is no feasible way of predicting which fields will respond to a particular nutrient, because single-element fertilizers are unavailable for field experiments and soil tests are unreliable or expensive.

A new system is needed so that farmers can decide for themselves which nutrients are needed on individual fields. We suggest the evaluation of a system of 'strip trials' set up by farmers and/or extension workers. They should apply a strip of single-element fertiliser on part of a rice field and observe or measure the yield response. The materials and instructions for conducting strip trials could be distributed as free samples with bags of urea, the fertilizer most widely use on rice in Asia. The assumptions behind strip trials are totally different from the usual system of 'blanket' recommendations, which are generally not followed, and, based on the Pharlap results, not justified.

Based on the results of the Pharlap project, optimum use of P, K and Zn would increase production of ranfed rice by 25% and provide of additional on-farm profit of $US900k to Antique rice farmers. Fertiliser companies stand to increase sales by about $US15/ha, based on the gaps between actual and optimal use of P, K and Zn (Menz et al 1989). Extrapolated to the Antique fertiliser market this represents additional annual revenue of $US450k. To the Philippine market it represents $US60 million and to the developing countries of Asia it represents $US2 billion. The fertilizer industry stands to benefit from additional sales of P, K and Zn and should support novel systems to promote efficient use of these nutrients. Strip trials should be evaluated to see if they contribute to this goal.

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