Site-Specific Nutrient Management for Maize in Favorable Tropical Environments of Asia

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Abstract

There is a growing demand for maize in Asia with significant potential for maize production in the favorable irrigated and rainfed environments but knowledge on yield potential, exploitable yield gaps, and constraints to improving productivity at the field level is still limited. On-farm experiments were conducted at 19 key production sites with hybrid maize in Indonesia, the Philippines, and Vietnam in 2004 to 2007 to develop and evaluate a new site-specific nutrient management approach for Asia. Compared to the farmers' practice, SSNM improved yield by about 0.8 to 1.2 Mg ha^{-1} across key sites in each country, but the full yield advantage of 1.5 to 1.7 Mg ha^{-1} with SSNM could often only be achieved once other constraints to yield improvement were addressed. One such constraint to higher yield was low planting density. The SSNM concept is now evaluated at wider scale using farmer participatory approaches.

Media summary

Further increases in maize yield with good economic return seem feasible in most favorable growing environments of Southeast Asia through relatively straightforward adjustments in plant population and nutrient management.

Key words

Maize, hybrid, site-specific nutrient management

Introduction

Maize is the second most important cereal crop in Asia, not only as a staple food, but also as a major component of feeds for the animal industry. The total area planted to maize in Southeast Asia is currently about 8.6 million hectares (M ha) with the largest areas in Indonesia (41%), the Philippines (29%), Thailand (13%), and Vietnam (12%) (FAO 2007). The growing demand in the region cannot be met despite the increase in domestic production and yield of maize in the last 15 years. Average national yield in Indonesia, Thailand, and Vietnam is only 3 to 4 t ha^{-1} (2 t ha^{-1} in the Philippines) and knowledge on yield potential, exploitable yield gaps, and constraints to improving productivity at the field level is still limited. In 2004, IPNI in partnership with key research institutes in Indonesia, the Philippines and Vietnam launched a multi-national research project to i) quantify and understand the yield potential of maize in favorable environments and ii) develop and evaluate a new site-specific nutrient management (SSNM) approach and best crop management practices for maize through on-farm research in major maize growing areas.

Materials and Methods

The SSNM concept was first developed for irrigated rice in Asia (Dobermann et al 2002; Witt et al 2007; IRRI 2007). With SSNM, farmers strive to adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources, including soil, crop residues, manures, and irrigation water.
The principles of SSNM for maize were developed through a series of researcher managed on-farm and on-station experiments covering a wide range of bio-physical and socio-economic conditions. On-

farm trials with farmer selected hybrid varieties were conducted for at least two seasons at project sites to estimate yield responses to the application of fertilizer N, P, and K and associated agronomic efficiencies (AE, kg grain increase per kg fertilizer nutrient applied). In the first year, a total of 120 on-farm experiments were set up in farmers' fields at 19 key maize growing sites in Indonesia, the Philippines, and Vietnam. Treatments included nutrient omission plots with ample supply of all nutrients except for the omitted (0-N, 0-P, and 0-K) to estimate nutrient-limited yield, a fully-fertilized NPK treatment with ample application of fertilizer N, P and K to estimate attainable yield, and a farmer's fertilizer practice (FFP) to obtain the actual yield in farmers fields' for comparison. Improved crop management (iCM) treatments were established at all sites but varied from site to site, depending on expected constraints to improving yield in farmers' fields. These treatments included increased planting densities (iPD) or the application of manure or lime.

The principles of SSNM were developed based on the obtained experimental data, updated as more data became available, and used to develop site-specific fertilizer recommendations for evaluation at project sites. Briefly, fertilizer N rates are estimated depending on the expected grain yield response to fertilizer N application and an expected AE. The SSNM approach further advocates sufficient use of fertilizer P and K to overcome deficiencies (fertilizer use based on yield response like for N) accounting to some extent for the nutrient removal with harvested products to avoid the mining of soil P and K.

Results and Discussion

The yield potential of maize was estimated for project sites in Indonesia, the Philippines, and Vietnam using the model Hybrid-Maize (Yang et al 2006). At a plant population of 65,000 plants ha^{-1}, the average potential yield varies from 10 Mg ha^{-1} to 16 Mg ha^{-1} depending on site and date of planting (data not shown). It should be noted that maize is grown under rain-fed conditions at all sites except for irrigated maize grown in Nueva Ecija in the Philippines so that it is not always possible to plant maize in a month that would promise the highest potential yield. By definition, potential yield is only determined by germplasm and climate without considering water availability. However, estimates of potential yield provide a good benchmark for actual and attainable yields estimated in farmers' fields. A comparison of actual, attainable, and potential yield for selected sites in Southeast Asia suggests substantial opportunities for Asian maize farmers to increase yield and profit (Table 1). Average farmers' yield is considerably lower than the attainable yield in farmers' fields with optimal crop management and ample nutrient supply. The maximum attainable yield was often close to the crop's climatic-genetic yield potential. As a general rule, optimal yield targets should probably be within 70 to 80% of potential yield in favorable irrigated or rainfed maize environments.

Table 1. Actual, attainable, maximum attainable, and simulated yield potential of maize at selected sites in Southeast Asia, 2004-2007. Data are the average of 5 farms per site in at least three seasons. Attainable yield was estimated in treatments with ample supply of fertilizer N, P, and K. The maximum attainable yield is the single highest yield observed an NPK treatment at each site. The simulated potential yield was estimated with Hybrid-Maize model (Yang et al 2006) using actual planting densities at project sites.

Site	Average farmers' yield (t/ha)	Average attainable yield (t/ha)	Maximum attainable yield (t/ha)	Simulated potential yield (t/ha)
Wonogiri, Central Java, Indonesia	4.9	5.7	7.3	12-14
Lampung, Indonesia	7.2	9.2	13.7	12-14
Nueva Ecija, Philippines	7.9	9.0	14.2	15-18
An Giang, Vietnam	8.3	8.8	10.3	14-16
CuM'gar, Dak Lak, Vietnam	6.2	7.8	12.0	14-15

Figure 1 provides an overview of yield responses to fertilizer application across sites in Indonesia, the Philippines, and Vietnam. In general, yield responses followed the order N >> P > K. In 75% of the cases, average yield responses to fertilizer N were < 6 Mg ha^{-1} in Indonesia, < 4 Mg ha^{-1} in the Philippines, and < 5 Mg ha^{-1} in Vietnam. Yield responses for fertilizer P and K were commonly less than 2 Mg ha^{-1}. The measured yield responses to fertilizer application were used to calculate the site-specific fertilizer N, P, and K requirements to achieve optimal yields. Fertilizer P and K rates were further adjusted to avoid soil nutrient depletion.

As shown in Figure 2, SSNM improved yield by 0.8 to 1.2 Mg ha^{-1} compared with the farmers' fertilizer practice (FFP) across all sites, but the full yield advantage of 1.5 to 1.7 Mg ha^{-1} with SSNM could often only be achieved once other constraints to yield improvement were addressed (SSNM+iCM and SSNM+iPD). One such constraint in Indonesia and Vietnam was low planting density.

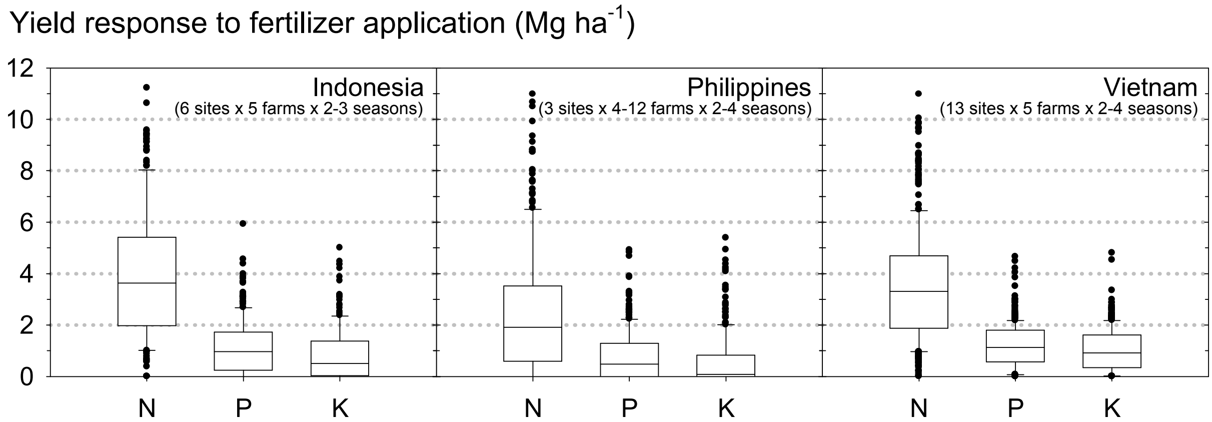

Figure 1. Yield responses to the application of fertilizer N, P, and K at project sites in Indonesia, the Philippines and Vietnam in 2004-2007. Boxes (with median) include 50% of all cases, whiskers mark 80% of all cases, and bullets are outliers.

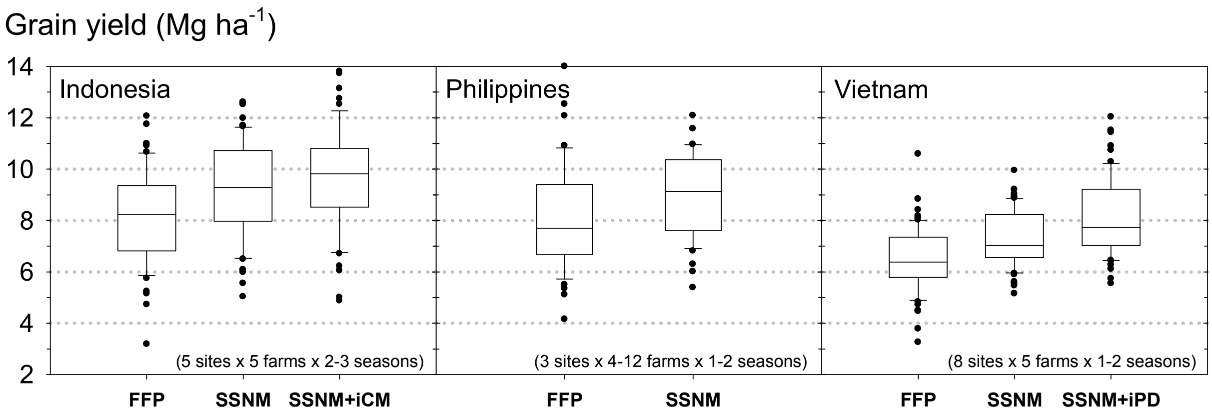

Figure 2. Yield with farmers' fertilizer practice (FFP), SSNM, and SSNM in combination with other site-specific improvements (e.g. improved crop management, iCM, or increased planting density, iPD). Excluded are sites with extreme drought (South Sulawesi, Indonesia) or those not including all treatments (three sites in Vietnam).

The agronomic and economic performance of SSNM was evaluated in detail at all project sites. In Indonesia, for example, significantly greater yield (+17%) and gross benefit over seed and fertilizer cost (+19%) were achieved with SSNM compared to farmer's practice despite larger investments in seeds (+10%) and fertilizer (+6%) across all sites except for drought prone sites in South Sulawesi in 2005/06 (data not shown). Compared to the farmers' practice, fertilizer P and particularly K was increased with SSNM at the expense of fertilizer N. Adjustments in fertilizer N, P, and K rates and better timing of fertilizer N applications were the key to achieving greater yield with SSNM.

Conclusions and outlook

In most favorable environments with irrigated or rainfed maize in Southeast Asia, further yield increases seem feasible with relatively straightforward adjustments in plant population and nutrient management. The SSNM concept has demonstrated significant agronomic and economic potential in these environments. Site-specific adjustment of nutrient management guidelines and robust approaches to an improved quantitative understanding of nutrient requirements to fill the deficit between plant demand and soil indigenous nutrient supply seem crucial for achieving high yield and profit. Wider scale evaluation of SSNM has begun using farmer participatory approaches at existing project sites. Farmer participatory evaluation is an important step towards wider scale delivery of more knowledge intensive technologies like SSNM for maize in the research-extension continuum of IPNI and its partners in Southeast Asia. This project maintains linkages with a similar initiative on rice by the Irrigated Rice Research Consortium (www.irri.org/irrc) providing opportunities for an ecological intensification of rice-maize systems.

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