A new site-specific nutrient management approach for maize in the favorable tropical environments of Southeast Asia

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Abstract

The demand for maize in Asia cannot be met despite increases in domestic production and yield in the last 15 years. Further increases in maize yield with good economic returns are feasible in most favorable growing environments of Southeast Asia through relatively straightforward adjustments in crop and nutrient management. More than 120 on-farm experiments with hybrid maize were conducted during 2004-2008 at 19 key production sites in Indonesia, the Philippines, and Vietnam to develop and evaluate a new site-specific nutrient management approach for Asia. Compared to the farmers' practice, SSNM improved yield by about 0.9 to 1.3 Mg/ha across sites in each country. The added net benefit of 184 US$/ha/crop with SSNM was attributed to increased yield rather than reduced costs of inputs. SSNM increased the agronomic efficiency of N fertilizer by 53% compared to the FFP.

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 8.8 million hectares (FAO 2009) with the largest areas in Indonesia (39%), the Philippines (31%), Vietnam (13%), and Thailand (11%). The rapid adoption of high-yielding hybrid maize varieties in Asia has led to significant yield increases in the favorable rainfed and irrigated maize growing areas. However, the growing demand in the region cannot be met despite the increase in domestic production and yield in the last 15 years. For example, Indonesia's maize production and yield continue to increase, and yet the country imported about one million tonnes of maize annually in the last five years (FAO 2009). The average yield of maize in Asia is only 3.9 t/ha (3 to 4 t/ha in Indonesia and Vietnam; 2 t/ha 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 launched a multi-national research project in partnership with key institutes in Indonesia, the Philippines, and Vietnam 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. The model Hybrid-Maize (Yang *et al.* 2006) estimates the climatic-genetic yield potential of maize to be in the range of 12 to 14 t/ha, indicating that there is a large scope for further increasing maize production in favorable environments by closing this yield gap.

Materials and Methods

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 or the application of manure or lime.

SSNM strategies were developed based on the obtained experimental data, updated as more data became available, and used to develop site-specific fertilizer recommendations that were evaluated in subsequent cropping seasons in comparison to the FFP. Data gathered on grain yield, fertilizer NPK use, AEN, fertilizer cost, revenue, and gross returns from all sites and seasons were pooled and pair-wise treatment differences (Δ) between FFP and SSNM were subjected to analysis of variance (ANOVA) using the SAS Proc Mixed model.

The site-specific nutrient management approach
Site-specific nutrient management is a set of nutrient management principles combined with good crop management practices that will help farmers attain high yield and achieve high profitability both in the short- and medium-term. The SSNM concept was first developed for irrigated rice in Asia (Dobermann *et al.* 2002; Witt *et al.* 2007; IRRI 2007), but the principles are generic and applicable to other crops. SSNM provides an approach for the timely application of fertilizers at optimal rates to 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.

Nitrogen (N)
The SSNM strategy for N includes the determination of the total fertilizer N requirement of a maize crop for a given yield target and the distribution of N applications into 2–3 splits to coincide with plant demand at critical growth stages. The total fertilizer N requirement is estimated from the expected grain yield response to fertilizer N and an expected AEN, with the assumption that a greater AEN can be achieved at higher yield responses. Under rainfed environments, adjustments in the timing of N application are needed to ensure sufficient moisture at the time of N application. The leaf color chart can be used to evaluate the plant N demand during the season and the need to adjust the total N rates.

Phosphorus (P) and Potassium (K)
The SSNM approach advocates the sufficient use of fertilizer P and K to overcome deficiencies while simultaneously accounting to some extent for the nutrient removal with harvested products, to avoid the mining of soil P and K. Thus, in addition to the fertilizer required to increase yield, SSNM considers a conservative P maintenance component (accounting for 75% of the P removal with grain) as well as a K maintenance component (accounting for 100% of the K removal with grain).

Results and Discussion
A comparison of the agronomic and economic performance between the SSNM treatment and the FFP is shown in Table 1.

Significantly greater yield (+16%) was achieved with SSNM across all crops and countries. Compared to the farmers' practice, average grain yields in SSNM increased by 0.89 Mg/ha in Indonesia, 1.16 Mg/ha in the Philippines, and 1.25 Mg/ha in Vietnam. Average straw yield increased significantly by 1.37 Mg/ha with SSNM (data not shown), representing a potential benefit in areas where farmers use straw as fuel, forage, or for soil improvement.

SSNM and FFP treatments differed in the amount of N, P, and K applied among the three countries. In the Philippines, N rates were 27.1 kg/ha higher in the SSNM compared to the FFP, but on average across the three countries, 16.1 kg/ha less N was applied in SSNM plots than in FFP. Fertilizer P and K rates with SSNM were slightly higher than in the FFP (+5 kg P/ha and +15 kg K/ha). SSNM led to large gains in N-use efficiency. Average AEN under SSNM rose to 25.1 kg/kg, an increase of 53% compared to the FFP. Better timing and splitting of fertilizer N applications during the season was probably the major reason to the increase in N-use efficiency.

Gross revenue was consistently higher for SSNM than FFP across the three countries. Despite larger investments in seeds (+11%, data not shown) and fertilizer (+6%), the SSNM strategy on average provided added net benefits of 140 US$ /ha/crop in Indonesia, 103 US$ /ha/crop in the Philippines, and 218 US$ /ha/crop in Vietnam.

Table 1. Effect of site-specific nutrient management on grain yield, AEN, fertilizer NPK use, revenue, cost for fertilizer, gross return over seed and fertilizer cost* (2005-2008).

		Treatment[B]					
	Levels	SSNM	FFP	□[c]	P>|T|[C]	Effects[D]	P>|F|[D]
Grain yield (GY)	All[a]	8.32	7.17	1.15	0.000	Country	0.167
(Mg/ha)	Indonesia	8.79	7.90	0.89	0.000	Site(Country)	0.009
	Philippines	8.52	7.36	1.16	0.007		
	Vietnam	8.09	6.85	1.25	0.000		
Agronomic efficiency	All	25.1	16.4	8.7	0.000	Country	0.939
of N (AEN)	Indonesia	29.7	21.2	8.5	0.000	Site(Country)	0.273
(kg grain kg/N)	Philippines	16.4	11.8	4.6	0.005		
	Vietnam	25.2	15.5	9.7	0.000		
N Fertilizer (FN)	All	151	167	-16.1	0.000	Country	0.889
(kg/ha)	Indonesia	157	192	-35.8	0.000	Site(Country)	0.166
	Philippines	156	129	27.1	0.017		
	Vietnam	148	166	-17.4	0.000		
P Fertilizer (FP)	All	36	31	5.0	0.007	Country	0.014
(kg/ha)	Indonesia	34	24	9.4	0.013	Site(Country)	0.058
	Philippines	32	12	19.8	0.000		
	Vietnam	38	38	0.1	0.961		
K Fertilizer (FK)	All	79	64	15.3	0.000	Country	0.146
(kg/ha)	Indonesia	77	51	25.6	0.019	Site(Country)	0.001
	Philippines	64	20	44.6	0.000		
	Vietnam	83	78	5.1	0.227		
Revenue (GR)	All	1,480	1,275	204.4	0.000	Country	0.167
(US$/ha)	Indonesia	1,564	1,405	158.7	0.000	Site(Country)	0.009
	Philippines	1,515	1,308	206.6	0.007		
	Vietnam	1,440	1,218	221.7	0.000		
Fertilizer cost (FC)	All	258.4	244.8	13.6	0.061	Country	0.000
(US$/ha)	Indonesia	255.1	236.4	18.7	0.272	Site(Country)	0.001
	Philippines	238.9	135.7	103.2	0.000		
	Vietnam	263.8	271.0	-7.2	0.361		
Gross returns over	All	1,155	971	184.0	0.000	Country	0.048
seed & fertilizer costs	Indonesia	1,246	1,106	140.3	0.000	Site(Country)	0.225
(US$/ha)	Philippines	1,199	1,096	102.6	0.099		
	Vietnam	1,110	892	218.1	0.000		

[A]All - all crops grown in Indonesia, Vietnam, and the Philippines from 2005 to 2008; Indonesia: n = 5 farms x 5 sites x 1-2 seasons; Philippines: n = 4-11 farms x 3 sites x 1 season; Vietnam: n = 5-13 farms x 11 sites x 1-2 seasons
[B]FFP - farmers' fertilizer practice; SSNM – site-specific nutrient management (average of SSNM±ICM);
[C]□= SSNM - FFP. P>|T| - probability of a significant mean difference between SSNM and FFP.
[D]Source of variation of analysis of variance of the difference between SSNM and FFP by farm; Prob>|F| = probability of a significant F-value.
[*] Average regional prices for 2004-2007.

Conclusions and outlook

Yield and profitability of maize in the favorable tropical environments of Southeast Asia can be further increased with improved crop and nutrient management practices. The SSNM concept demonstrated significant agronomic and economic potential in these environments and merits wide-scale dissemination. A number of delivery tools will be released in 2010 to facilitate the introduction of general best management practice for maize in large scale extension campaigns in Indonesia, the Philippines, and Vietnam. These include site-specific Quick Guides on SSNM generated by the *Nutrient Expert for Hybrid Maize* - a new, computer-based decision support software, country-specific training videos on relevant aspects of crop and nutrient management, and a Practical Guide to nutrient management.

Acknowledgements
The authors wish to thank the following scientists and their institutions for their invaluable contributions to this project. Indonesia: Mrs. Setia Sari Girsang (AIAT North Sumatera), Mr. Andarias Makka Murni (AIAT Lampung), Mr. Supadmo (AIAT Central Java), Mr. Suwono (AIAT East Java), Mr. Peter Tandisau (AIAT South Sulawesi), Dr. Sania Saenong (ICRI), Dr. Subandi (ICRI), Dr. Diah Setyorini and Dr. Fahmuddin Agus (ISRI), and Dr. Sunendar Kartaatmadja (IPNI-IPI). Philippines: Dr. Romeo Labios (UPLB), Dr. Apolonio Ocampo (IPB), Mrs. Jocelyn Labios (UPLB), Dr. Cynthia Medina (UPLB), Mr. Hermenegildo Gines (PhilRice), Mr. Carmelito Lapoot (NOMIARC), Mr. Severino Tumamang (CVIARC). Vietnam: Dr. Pham Sy Tan (CLRRI), Dr. Tran Thuc Son (SFRI), Dr. Do Trung Binh (IAS), Dr. Nguyen My Hoa and Dr. Ngo Ngoc Hung (Cantho University), Dr. Ton Nu Tuan Nam (WASI). We are very grateful to Dr. Achim Dobermann for his advice and guidance in the development and implementation of this project.

Funding for this project is provided by the International Fertilizer Industry Association (IFA), Canpotex International Pte. Ltd., the International Plant Nutrition Institute (IPNI) and the International Potash Institute (IPI). Additional direct and indirect support provided by the collaborating national agricultural research and extension systems is gratefully acknowledged.

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