Development and Evaluation of Nutrient Expert® Decision Support Tool for Cereal Crops

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Nutrient Expert® (NE) is a computer-based decision support tool that uses the principles of site-specific nutrient management for developing fertiliser recommendations tailored to a specific field or growing environment. Results of field evaluation have shown that NE is effective in providing recommendations that can increase yields and profits compared with farmers' current practices. NE accounts for the important factors affecting site-specific recommendations, which makes it an excellent tool for providing tactical information to crop advisors and farmers as well as strategic information to high-level decision makers. NE is also a suitable starting point for developing nutrient management tools to reach more users.

The demand for increased cereal production to feed an increasing world population will not be met just by the expansion in cultivated area, but more by intensifying production of wheat, rice and maize. Currently, cereal yields are only 40 to 65% of their potential, mostly because nutrient management does not consider crop's dynamic response to the environment. Intensification will therefore need nutrient management that produces high yields, while preserving soil quality and protecting the environment.

Site-specific nutrient management (SSNM) is a set of nutrient management principles, which aims to supply a crop's nutrient requirements tailored to a specific field or growing environment. Although SSNM has been proven to increase yields and productivity in on-farm trials, there has been little acceptance. The reason being many extension agents still perceive SSNM as complex, requiring an understanding of concepts and methods outside their experience. A simple nutrient decision support tool based on the principles and guidelines of SSNM, such as Nutrient Expert® (NE), will help crop advisors develop strategies to manage fertiliser N, P and K tailored to a farmer's field or growing environment. As a computer-based decision support tool, NE combines all the steps and guidelines in SSNM into a simple software tool tailored for crop advisors, especially the not-so-technical users such as the extension agents in developing countries.

The conceptual framework used in the development of NE is applicable to any cereal crop and geographic location. The algorithm for calculating fertiliser requirements in NE is determined from a set of on-farm trial data using SSNM guidelines. In SSNM, the N, P and K requirements are based on the relationships between balanced uptake of nutrients at harvest and grain yield (Buresh et al., 2010; Setiyono et al., 2010). This

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Dr. Mirasol Pampolino (far right) **visiting the Nutrient Expert® validation trials** at the CSISA hub site in Bheemarayanagudi, Karnataka with Dr. Kaushik Majumdar (second from right) and Dr. T. Satyanarayana (far left) and staff from CIMMYT, and UAS Raichur.

relationship is called the internal nutrient efficiency and is predicted using the quantitative evaluation of the fertility of tropical soils (QUEFTS) model (Janssen et al., 1990). The fertiliser requirement for a field or location is estimated from the expected yield response to each fertiliser nutrient, which is the difference between the attainable yield and the nutrient-limited yield. These parameters are determined from nutrient omission trials in farmers' fields, while attainable yield is the yield for a typical year at a location using best management practices without nutrient limitation. Nutrient-limited yield is that when only the nutrient of interest is omitted. The amount of nutrients taken up by a crop is directly related to its yield so that the attainable yield indicates the total nutrient requirement and the nutrient-limited yield indicates the indigenous nutrient supply (Dobermann et al., 2003). The yield response indicates the nutrient deficit, which must be supplied by fertilisers. Nutrient Expert® follows SSNM guidelines for fertiliser application and split dressings, which consider the crop's nutrient demand at critical growth stages (Witt et al., 2009; IRRI, 2011).

Table 1. Characteristics of the sites for the field evaluation of Nutrient Expert® for Hybrid Maize in Indonesia and the Philippines, 2010-2011.

Country & Site No.	Province	District/Municipality	Ecosystem†	Cropping pattern	Farmers
Indonesia					
1	East Java	Kediri	IR	Rice-rice-maize	5
2	Lampung	Punggur	RF	Maize-maize	5
3	North Sumatra	Langkat	RF	Maize-maize	5
4	North Sumatra	Langkat	IR	Rice-rice-maize	4
5	South Sulawesi	Bone	RF	Maize-maize	3
Philippines					
1	Pangasinan	Bayambang	RFSI	Rice-maize	5
2	Laguna	Calamba	RF	Maize-maize	3
3	Occidental Mindoro	Abra de Ilog	RFSI	Rice-maize	4
4	Iloilo	Cabatuan	RF	Maize-maize	6
5	Negros Occidental	Murcia	RF	Maize-maize	7
6	Davao	Tugbok	RF	Maize-maize	2
7	Maguindanao	Datu Odin Sinsuat, Sultan Mastura, Ampatuan, Sultan Kudarat	RF	Maize-maize	4

† IR = irrigated, RF = fully rainfed, RFSI = rainfed with supplemental irrigation.

Table 2. Agronomic and economic performance of Nutrient Expert® for Hybrid Maize at five sites (3 to 5 farmers per site) in Indonesia and seven sites (2 to 7 farmers per site) in the Philippines, 2010–2011.

	-------- Indonesia (n = 22) --------				-------- Philippines (n = 31) --------			
Parameter	FFP	NE	(NE – FFP)†		FFP	NE	(NE – FFP)†	
Grain yield, t/ha	7.5	8.4	+0.9	***	7.5	9.1	+1.6	***
Fertiliser N, kg/ha	173	160	-12	ns	107	132	+25	**
Fertiliser P, kg/ha	19	14	-4	*	12	15	+4	**
Fertiliser K, kg/ha	23	34	+11	**	18	29	+11	**
Fertiliser cost, US$/ha	126	126	0	ns	176	240	+64	***
GRF‡, US$/ha	1,761	2,032	+271	***	1,738	2,117	+379	***

***, **, *: significant at 0.001, 0.01 and 0.05 level respectively; ns = not significant
† Statistical analysis was performed with JMP version 8 (SAS Institute, 2009) using Mixed Procedure with sites as random effects.
‡GRF refers to the gross return above seed and fertiliser costs; estimated using actual local prices of seed, fertiliser and maize grain at US$1 = IDR 8,850 (Indonesia), Php 43 (Philippines).

Nutrient Expert® estimates the attainable yield and yield response to fertiliser from site information using decision rules developed from on-farm trials. It uses:

(a) Characteristics of the growing environment like water availability (irrigated, fully rainfed, rainfed with supplemental irrigation) and any occurrence of yield-limiting constraints such as flooding, drought etc.;
(b) Soil fertility indicators like soil texture, soil color and organic matter content, soil test for P or K (if any), historical use of organic materials (if any), problem soils (if any);
(c) Crop sequence in the farmer's cropping pattern;
(d) Crop residue management and fertiliser inputs; and
(e) Farmers' current yields.

The development of NE is done through collaboration with crop advisors from both public and private sectors, as well as with scientists and extension specialists to ensure that NE meets users' needs and preferences, thereby increasing the likelihood of its adoption. Collaboration is carried out through a series of dialogues, consultations and partnerships towards (a) collection of locally-available agronomic data and information, (b) integration of local user's preferences such as use of local language, measurement units, locally-available fertiliser sources, etc. and (c) field testing, evaluation and refinement of the NE software.

Nutrient Expert® for Hybrid Maize

As NE can be applied to any cereal crop, the NE for Hybrid Maize (NEHM) was developed for favorable, tropical rainfed and irrigated environments. It was designed to ask simple questions, which can be answered from existing information for a field or recommendation domain. The questions were grouped into five modules, viz., (1) current practice, (2) planting density, (3) SSNM rates, (4) sources and splitting and (5) profit analysis. The first three modules include questions that determine attainable yield and yield responses to fertiliser. The SSNM rates module provides N, P and K requirements for the selected attainable yield.

Consistent with SSNM, which promotes the 4Rs of nutrient stewardship (right source, right rate, right time and right place), NEHM specifies the amount and timing of fertiliser to apply, including split applications. In the sources and splitting module, NEHM recommends two or three splits for N, that all P be applied at or soon after sowing and that K be applied once or twice depending on the rate. It selects among fertilisers that the user specifies, choosing those whose nutrient contents match the requirement for optimal split dressings. It also recommends optimum plant population specifying both plant and row spacing. The sources and splitting guidelines are location-specific with each recommendation.

The SSNM strategies for maize in Southeast Asia (Witt et al., 2009) comprised the algorithm for calculating fertiliser N, P and K requirements in NEHM. These SSNM strategies are based on known attainable yield and yield responses and were developed using 2004 to 2008 data from on-farm trials with hybrid maize at 19 important sites in Indonesia, Philippines and Vietnam. It provided a range of attainable yields and yield responses to fertiliser N, P and K across diverse environments characterised by variations in amount and distribution of rainfall, varieties and crop durations, soils and cropping systems.

The NEHM model developed was validated in Indonesia and the Philippines in sites without nutrient omission trial data. Existing site and farming information were used to estimate attainable yield and expected yield responses to fertiliser and generate fertiliser recommendation for each field or location. Some users developed fertiliser guidelines for a field, using an individual farmer's data, while others used it for a recommendation domain using data from several representative farmers. The domain-level recommendations were used to develop quick guides for maize for larger geographic areas such as municipalities or districts.

The NEHM recommendations were tested in farmers' fields (plot size ≥ 0.1 ha) against farmer's fertiliser practice (FFP) in 2010–2011 at five sites in Indonesia (3 to 5 farmers per site) and seven sites in the Philippines (2 to 7 farmers per site) (**Table 1**). The sites included key maize production areas with maize-maize or rice-maize cropping sequence under favorable rainfed as well as irrigated environments in the two countries.

NEHM increased yield and profit of farmers in both Indonesia and the Philippines (**Table 2**). Results from 22 farmers' fields across five sites in Indonesia showed that NEHM increased yield by 0.9 t/ha, which increased the gross return over seed and fertiliser costs (GRF) by US$270/ha over FFP. Compared with FFP, NEHM recommendations reduced fertiliser P (–4 kg/ha), increased fertiliser K (+11 kg/ha) and did not significantly change fertiliser N. In the Philippines (with data from 31 fields across seven sites), NEHM increased yield by 1.6 t/ha and GRF by US$380/ha compared with FFP (**Table 2**). Compared with FFP, NEHM gave higher rates of all three nutrients (+25 kg N/ha, +4 kg P/ha and +11 kg K/ha), which substantially increased fertiliser costs (US$64/ha), but still increased profit by about six times the additional investment in fertiliser.

NEHM increased yield and economic benefits of farmers in Indonesia and the Philippines by providing a nutrient management strategy tailored to field-specific or domain-specific conditions. NEHM recommendations ensured that sufficient amount of all nutrients (N, P, K, as well as secondary and micronutrients when deficient) needed to attain the yield goal were applied at the critical growth stages of the maize crop. In Indonesia, farmers' nutrient application rates were not always less than NEHM (**Table 2**), indicating that the yield increase with NEHM could have been due to the balanced application of nutrients, as well as optimising the N splitting ratio and application timing, thus improving the efficiency of applied fertiliser nutrients. In the Philippines, the increase in yield with NEHM was largely due to the increased rates of nutrients applied at critical growth stages as compared to the farmers' nutrient rates and timing of application.

Summary

Results of the field evaluation of NEHM in Indonesia and the Philippines demonstrated the ability of NE to increase farmer's yield and income across a range of climates, soil types and cropping systems. Nutrient Expert® provides crop advisors with a simpler and faster way to use SSNM and it enables strategic formulation of nutrient management guidelines for maize and other crops in different geographic regions and countries. Nutrient Expert® allows the determination of a range of yield goals taking into account the potential yield for the specific area, the attainable yield with optimal nutrient management as well as the farmer's objectives (food security or income) and resources. This provides added value in moving from what are now blanket recommendations to developing nutrient management recommendations that match the goals of the farmer and conditions in specific sites. BC-SA

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