Optimising fertilizer formulations

for smallholders in Asia and Africa

by Dr. Mirasol Pampolino, Deputy Director,
Southeast Asia Programme, **International Plant Nutrition Institute (IPNI)**

Introduction

The demand for increased cereal production to feed an increasing world population would be better met by intensifying production of wheat, rice and maize to increase attainable yields, rather than by expanding cultivated areas.

> *"The amount of nutrients taken up by a crop is directly related to its yield*

Currently, yields of these crops are only at 40–65pc of their potential mainly because fertilizer application practices are not optimised for the crop's dynamic response to the environment. The aim is to increase potential yields up to 70-80pc.

Optimising fertilizer recommendations for cereal grains must use a nutrient management approach that accounts for both the crop's demand for nutrients and indigenous soil nutrient supply. Soil testing has been the established tradition when it comes to assessing soil nutrient supply in farm fields. However, experience by IPNI staff with smallholder farmers in Asia and Africa indicates that soil testing is rarely used because of economic, access and timeliness issues.

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. It aims to (a) account for indigenous soil nutrient sources, including crop residues and manures; and (b) apply fertilizer at optimal rates and at critical growth stages to meet the deficit between the nutrient needs of a high-yielding crop and the indigenous soil nutrient supply.

Nutrient Expert (NE) is a computer-based decision support tool that helps crop advisors formulate fertilizer guidelines based on SSNM principles. NE considers the most important factors affecting nutrient management recommendations in a particular location and enables crop advisors to provide farmers with fertilizer guidelines that are suited to their farming conditions. The tool uses a systematic approach of capturing site information that is important for developing a location-specific recommendation. Yet, NE does not require a lot of data nor very detailed information as in the case of many sophisticated nutrient decision support tools, which could overwhelm the user. If a soil test is available it can be included, but is not necessary to get a recommendation. It allows the users to draw the required information from their own experience, the farmers' knowledge of the local region, and the farmers' practices. NE can use experimental data, but it can also estimate the required SSNM parameters using existing site information.

Nutrient Expert: Conceptual framework and information requirement

The conceptual framework used in the development of NE is applicable to any cereal crop and geographic location. The algorithm for calculating fertilizer requirements in NE is determined from a set of on-farm trial data using SSNM guidelines. The N, P and K requirements are based on the relationships between balanced uptake of nutrients at harvest and grain yield. This relationship is called internal nutrient efficiency and is predicted using the quantitative evaluation of the fertility of tropical soils (QUEFTS) model. The fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer 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 obtained 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. The yield response indicates the nutrient deficit, which must be supplied by fertilizers. Consistent with 4R Nutrient Stewardship, NE follows the SSNM guidelines for fertilizer application and split dressings to consider the crop's nutrient demand at critical growth stages. In the absence of trial data for a specific location, NE estimates the attainable yield and yield response to fertilizer from site information using decision rules developed from on-farm trial data. Finally, the NE decision support tool also allows farmers to set their own yield goal, which maybe less than the location attainable yield. This expands the ability of farm advisors to making fertilizer recommendations to farmers across a wide socioeconomic spectrum.

Farmer using Nutrient Expert to develop fertilizer recommendations for Indian farmers

NE only requires information that can be easily provided by a farmer or a local expert. The set of information includes:

- Farmers' current yield
- Characteristics of the growing environment or estimate of the attainable yield (if known)
- Soil fertility indicators (e.g. soil texture and color, historical use of organic inputs) or estimates of yield responses to fertilizer N, P and K (if known)
- Crop sequence in the farmer's cropping pattern
- Crop residue management and fertilizer and organic manure inputs

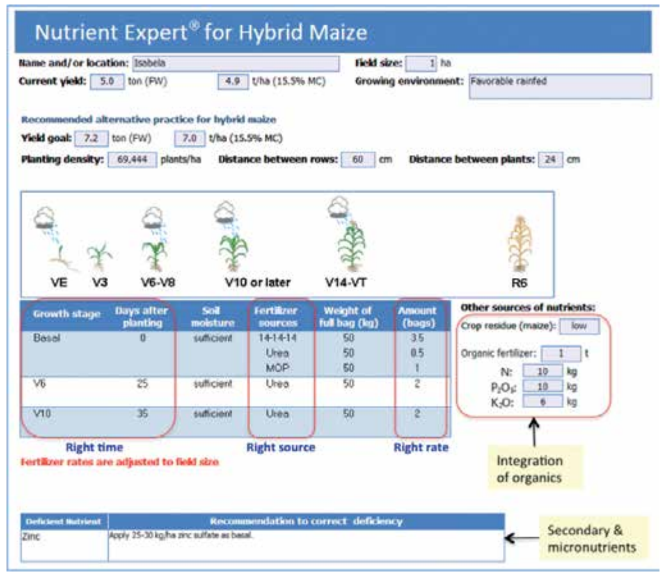
Effect of NE on yield, fertilizer use, and economic benefits in wheat, maize, and rice

Field-testing of NE recommendations against farmers' fertilizer practice (FFP), across a large number of farmers and diverse growing conditions, revealed improved yields and economic benefits with NE for maize, wheat and rice (Table 1). Compared with FFP, NE increased maize yield by 24pc (1.3 t/ha) in India and by 13pc (1.1 t/ha) in the Philippines. With NE, gross profit in maize increased by USD256/ha in India and USD267/ha in the Philippines. In India, NE also increased yields over

FFP in wheat by 20pc (0.79 t/ha) and in rice by 25pc (1.16 t/ha), which resulted in increased gross profit by USD163/ha in wheat and by USD224/ha in rice. In India, NE reduced fertilizer N and P rates, but increased K rates for maize and wheat. For rice, NE increased fertilizer N rate, but rates for P and K were comparable to FFP. This lack of response to K in these rice trials reflects the field work being carried out in West Bengal, where farmers regularly use compound fertilizer with K. For maize in the Philippines, NE increased the rates of fertilizer P and K but fertilizer N was comparable with FFP.

NE recommendations varied across locations and crops reflecting the differences in site characteristics and farming practices (climate, soil, cropping system, farmers' yield and inputs, residue management, etc.), which affect attainable yield and crop response to fertilizer. In most cases, K rates were higher with NE than with FFP whereas N and P rates either increased or decreased depending on the crop and geography or growing conditions. This highlights how NE promotes balanced application of nutrients and efficient use of fertilizers by providing recommendations based on crop nutrient requirements tailored to location-specific conditions. As observed in India for maize, wheat and rice, and in the Philippines for maize, NE recommendations can increase farmers' yield and economic benefits. Despite the possibility of increasing input costs due to increased fertilizer requirement, the added revenue from the yield increase will still be much higher than the additional costs, suggesting an attractive return on investment to fertilizer.

Figure 1. Nutrient Expert for hybrid maize output page, showing fertilizer source, rate and time of application, along with integration of organic nutrient sources and secondary and micronutrients



Effect of NE in reducing fertilizer impact on the environment

In China, where farmers' yields are already close to attainable yield due to high, but mostly unbalanced fertilization, NE improved fertilizer use efficiency while maintaining high yields (Table 2). Across a large number of farmers' fields, compared with FFP, NE increased the recovery efficiency of N (REN, pc) from 17.5pc to 30.2pc in maize, from 18.5 to 29.1pc in wheat, and from 25pc to 34.2pc in rice. When compared with local recommendations based on soil test (ST), REN values with NE were higher for all the three crops. NE also increased the agronomic efficiency of N (AEN, kg increase in yield/kg N applied) over FFP and ST in the three crops. The increase in N use efficiency could be attributed to (a) the substantial reduction in fertilizer N with balanced application of P and K and (b) the split application of fertilizer N corresponding to the crop's demand for N at critical growth stages.

In northwest India under conventional tillage and no-tillage based wheat production system, NE-based recommendations showed lower estimates of greenhouse gas emissions (GHG, expressed as kg CO2 equivalent per ton of wheat yield) than FFP. This finding indicates lower global warming potential with NE than FFP while ensuring higher yields and profits. These results show that fertilizer recommendations, guided by 4R Nutrient Stewardship of applying the right source of nutrients, at the right rate, at the right time, and in the right place, will not only produce high yields but also improve fertilizer use efficiency, thereby minimizing the fertilizer impact on the environment.

Table 1. Yield, fertilizer use, and gross profit in maize, wheat, and rice using Nutrient Expert® (NE) and farmer's fertilizer practice (FFP).

Parameter	Unit	Maize (2010-14)				Wheat (2010-14)		Rice (2014-15)	
		India (n = 412)		Philippines (n = 190)		India (n = 701)		India (n = 323)	
		FFP	NE	FFP	NE	FFP	NE	FFP	NE
Grain yield	t/ha	5.38	6.65	8.29	9.39	3.98	4.77	4.63	5.78
Fertilizer N	kg/ha	151	145	159	162	136	128	85	111
Fertilizer P_2O_5	kg/ha	63	46	30	48	64	60	39	34
Fertilizer K_2O	kg/ha	43	64	25	43	24	78	47	49
Gross profit*	USD/ha	995	1251	2008	2272	833	996	861	1085

*Gross profit refers to the gross returns above fertilizer cost, calculated using actual local prices for grain and fertilizer.

Table 2. Yield, fertilizer use, recovery efficiency of N (REN), and agronomic efficiency of N (AEN) in maize, wheat, and rice using farmer's fertilizer practice (FFP), Nutrient Expert (NE), and soil test-based recommendations (ST) in China.

Parameter	Unit	Maize (n = 290)			Wheat (n = 541)			Rice (n = 137)		
		FFP	NE	ST	FFP	NE	ST	FFP	NE	ST
Grain yield	t/ha	7.9	8.0	8.3	9.9	10.2	10.3	7.8	8.1	7.9
Fertilizer N	kg/ha	271	162	237	230	158	202	170	156	162
Fertilizer P_2O_5	kg/ha	118	82	105	62	56	57	59	70	62
Fertilizer K_2O	kg/ha	50	74	73	47	68	75	85	87	96
REN	pc	17.5	30.2	22.5	18.5	29.1	23	25.0	34.2	28.0
AEN	kg/kg	5.2	8.6	6.3	7.8	11.8	10	12.2	15.0	13.2

Nutrient Expert tools for different crops and geographies

The robust framework of NE has enabled the application of the NE concept in different crops (maize, wheat, rice, and soybean) and geographies in Asia and Africa. Versions of the NE software are available for download to personal computers, tablets and smart phones. Field-validated versions for different crops and geographies are available for free download at software.ipni.net: (a) NE Maize – China, India, Philippines, Indonesia, and Vietnam, (b) NE Wheat – China and India, (c) NE Rice – China and India, (d) NE Soybean – China. Field-testing and validation of beta versions are ongoing in Africa for: (a) NE Maize – Ethiopia, Kenya, Nigeria, and Zimbabwe, (b) NE Wheat – Morocco, Algeria, and Tunisia. ■