Nutrient Expert®–Maize: A Tool for Increasing Crop Yields and Farm Profit

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Nutrient Expert®-based fertiliser recommendations were validated and demonstrated across 191 major maize growing locations in southern India and Odisha showed an overall increase in yield by 1.1 t/ha over the current farmer fertiliser practice. It also helped in improving the profitability of maize farmers in the region. Nutrient Expert®, which follows the principles of the 4R Nutrient Stewardship approach, proved to be a boon to smallholder farmers in the region.

Nutrient Expert® (NE), a nutrient decision support tool, is developed by the International Plant Nutrition Institute (IPNI) following the principles of 4R Nutrient Stewardship and site-specific nutrient management (SSNM). NE is an easy-to-use, interactive computer-based decision support tool that can rapidly provide nutrient recommendation for an individual farmers' field in the presence or absence of soil testing data (Pampolino et al., 2012). It was developed in 2010-11 in collaboration with stakeholders including scientists, extension agents, and crop advisors from both government and private organisations. The NE provides crop advisors with a simple and rapid tool to apply SSNM principles in individual farmer's fields through the use of existing site information. Besides providing location specific nutrient recommendations, the tool has options to tailor recommendations based on those resources available to the farmers.

Comparative performance of Farmer Practice (left farmer), Nutrient Expert® (right farmer) and State Recommendation (Dr. Pattanayak standing near the SR treatment).

Nutrient Expert® for hybrid maize, a MS Access-based computer application consists of five working modules. Current Nutrient Management Practice, the first module in the software documents the history of maize yields obtained in the farmers' fields and records the corresponding extent of nutrients applied by the farmers both through organic and inorganic fertiliser sources. The Planting Density module decides whether or not the farmer is practicing an optimum plant population in his/her maize field and suggests a suitable plant population in the case of farmer's not practicing an optimum planting density. SSNM Rates, the third and the most critical module of the software, initially establishes an attainable yield target considering the growing environment of the farmer's field. It estimates the indigenous nutrient supplying capacity (contribution from crop residue recycling, addition of organic manures, residual benefit from the previous crop) of the farmer's field, determines yield responses to application of major NPK nutrients and finally arrives at the most appropriate nutrient recommendation adequate for obtaining the targeted attainable yield. The Sources and Splitting module transforms the nutrient rates into fertiliser sources available at farmer's door step and provides a final 4R compliant (i.e., Right Source, Right Rate, Right Time and Right Place) recommendation report to the farmer. The Profit Analysis module compares the cost economics associated with both the SSNM and the farmers' practice and suggests whether or not it is profitable of practicing NE-based fertiliser recommendation.

The development and validation of NE during 2010-12, including the accumulation of promising on-farm results, led to the official launching of the NE for free public use on 20 June 2013. This paper summarises the results obtained from the on-farm validation experiments conducted in the southern region of IPNI South Asia Program and compares the performance of NE-based fertiliser recommendations over the other existing nutrient management practices. On-farm experiments evaluating the performance of NE over SR (official fertiliser recommendations by respective states) and FP (farmers' fertiliser application practice) were conducted at 191 major maize-growing sites across Andhra Pradesh, Karnataka, Tamil Nadu, and Odisha. The comparative experiments were distributed in both the *kharif* and *rabi* seasons, and were conducted in varying maize-growing environments, under rainfed and assured irrigated conditions. The study area covered Krishna, Godavari, Guntur and Prakasam districts of Andhra Pradesh; Warangal, Karimnagar, Ranga Reddy and Medak districts of Telangana; Dharwad, Raichur, Bellary, Gulbarga, Yadgir and Bangalore districts of Karnataka; Perambalur, Dindigul, Than-

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

Table 1. Comparison of Nutrient Expert® (NE) estimated yield responses and the actual on-farm responses.

	NE-estimated response, kg/ha						Actual on-farm response, kg/ha					
	N		P_2O_5		K_2O		N		P_2O_5		K_2O	
Region	Mean	CV, %	Mean	CV, %	Mean	CV, %	Mean	CV, %	Mean	CV, %	Mean	CV, %
Andhra Pradesh	5,573	26	1,287	55	260	45	4,351	36	2,730	60	2,023	63
Karnataka	4,026	23	1,026	58	1,013	31	4,900	17	1,913	47	900	49
Tamil Nadu	3,500	16	625	120	500	115	2,433	48	492	96	447	51
Odisha	3,484	25	1,081	36	532	48	3,125	20	2,210	70	1,135	22

javur, and Coimbatore districts of Tamil Nadu; Nabarangapur, Kalahandi, Sambalpur, Puri and Cuttack districts of Odisha during the kharif and rabi seasons of 2011-13. The experiments were carried out by IPNI in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT), the Directorate of Maize Research (DMR), state agricultural universities (ANGRAU, Hyderabad; UAS Dharwad; UAS Raichur; TNAU Coimbatore; and OUAT Bhubaneswar), fertiliser industry, and farmers. The information on current nutrient management by farmers was collected through a questionnaire by all the stakeholder groups and NE-based fertiliser recommendations were tested against fertiliser recommendations followed in SR and FP. NE was evaluated in terms of NE- estimated attainable yield versus actual maize yields, NE-estimated crop responses versus actual crop responses determined through omission plot technique, and performance of NE over SR and FP was evaluated in terms of fertiliser use, maize grain yield, fertiliser cost, and gross returns above fertiliser cost (GRF).

Comparison of NE-estimated Attainable Yield and Actual Maize Yield

NE is capable of estimating the major nutrient requirement for a practical and challenging yield target established by the software under the SSNM Rates module. The comparative figure (**Figure 1**) showing the NE-estimated attainable yields and the actual maize yields recorded in the farmer fields indicated that NE-based fertiliser recommendations proved to be successful in reaching the yield targets estimated by the software. The NE-estimated average attainable yield targets during the kharif season were 8.3, 8.4, 8.3, and 6.0 t/ha in the respective states of Andhra Pradesh, Karnataka, Tamil Nadu and Odisha. The corresponding average actual maize yields realised in these states were 7.9, 8.2, 9.1. and 5.4 t/ha indicating that fertiliser recommendations developed using NE successfully helped in meeting the targeted attainable yields. The actual maize yields recorded in farmer fields were higher than the NE-estimated attainable yields during the

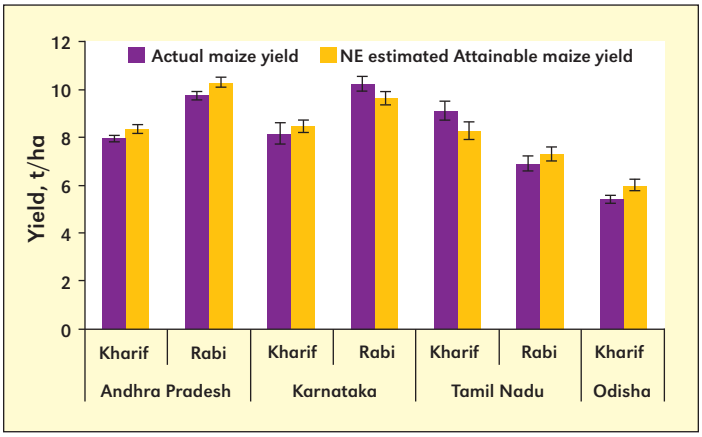

Figure 1. Comparison of Nutrient Expert® (NE)-estimated attainable maize yield versus actual maize yield.

Table 2. Comparison of nutrient use (kg/ha) between the Nutrient Expert® (NE)-based fertiliser recommendation and Farmer's Practice (FP).

	Kharif (monsoon season)				Rabi (winter season)			
Parameter	NE	FP	NE-FP		NE	FP	NE-FP	
ANDHRA PRADESH	(n = 44)				(n = 51)			
Fertiliser N	110-190 (169)	136-550 (196)	-42	***	150-257 (211)	121-534 (254)	-43	*
Fertiliser P_2O_5	17-84 (61)	25-230 (123)	-62	**	27-92 (55)	21-79 (48)	7	***
Fertiliser K_2O	18-143 (87)	38-150 (80)	7	ns	25-105 (70)	0-168 (64)	6	ns
KARNATAKA	(n = 27)				(n = 11)			
Fertiliser N	106-185 (152)	80-191 (135)	17	ns	110-190 (154)	80-218 (130)	24	ns
Fertiliser P_2O_5	20-81 (46)	46-138 (85)	-39	***	17-64 (42)	58-115 (77)	-35	***
Fertiliser K_2O	22-104 (66)	0-110 (59)	7	ns	29-81 (57)	0-75 (29)	28	*
TAMIL NADU	(n = 12)				(n = 12)			
Fertiliser N	130-210 (182)	147-332 (225)	-43	*	130-150 (148)	95-360 (210)	-62	*
Fertiliser P_2O_5	27-47 (42)	48-79 (67)	-25	***	28-47 (39)	25-258 (111)	-72	*
Fertiliser K_2O	29-55 (43)	48-352 (201)	-158	***	22-59 (31)	50-270 (128)	-97	**
ODISHA	(n = 34)							
Fertiliser N	110-170 (141)	27-367 (103)	38	***	-	-	-	-
Fertiliser P_2O_5	18-67 (41)	20-115 (52)	-11	ns	-	-	-	-
Fertiliser K_2O	21-104 (46)	0-192 (59)	-13	ns	-	-	-	-

***, ** and * significant at $p < 0.001$, 0.01 and 0.05 levels; ns = non-significant. NE, FP and SR = Nutrient Expert®, Farmer Practice and State Recommendation. Values in parenthesis represent mean values.

Table 3. Performance of Nutrient Expert® (NE)-based recommendations for yield and economics of maize in southern region.

		Kharif (monsoon season)							Rabi (winter season)						
Parameter	Unit	NE	FP	SR	NE-FP		NE-SR		NE	FP	SR	NE-FP		NE-SR	
ANDHRA PRADESH (n = 95)		(n = 44)							(n = 51)						
Grain Yield	kg/ha	7,943	6,525	7,297	1,418	***	646	ns	9,736	8,689	8,813	1,047	***	923	***
Fertiliser Cost	₹/ha	5,398	5,996	4,991	-598	ns	407	***	5,515	7,740	5,220	-2,225	***	295	ns
GRF	₹/ha	74,032	59,254	67,979	14,778	***	6,053	***	91,845	79,150	82,910	12,695	***	8,935	***
KARNATAKA (n = 38)		(n = 27)							(n =11)						
Grain Yield	kg/ha	8,153	7,591	7,033	562	ns	1,120	**	10,214	8,831	9,835	1,383	***	379	**
Fertiliser Cost	₹/ha	4,455	5,385	5,543	-930	**	-1,088	**	4,943	4,481	5,543	462	ns	-600	***
GRF	₹/ha	77,075	70,525	64,787	6,550		12,288		97,197	83,829	92,807	13,368		4,390	
TAMIL NADU (n = 24)		(n = 12)							(n = 12)						
Grain Yield	kg/ha	8,774	8,154	7,622	620	**	1,152	ns	7,405	6,550	7,114	855	***	291	ns
Fertiliser Cost	₹/ha	4,232	8,488	4,514	-4,256	***	-282	***	3,546	8,395	5,960	-4,849	**	-2,414	***
GRF	₹/ha	83,230	73,058	71,988	10,172	***	11,242	ns	68,099	57,106	67,595	10,993	***	504	ns
ODISHA (n = 34)		(n = 34)							-						
Grain Yield	kg/ha	5,394	3,611	4,334	1,783	***	1,060	***	-	-	-	-	-	-	-
Fertiliser Cost	₹/ha	3,445	4,264	2,638	819	ns	807	***	-	-	-	-	-	-	-
GRF	₹/ha	50,495	31,846	40,702	18,649	***	9,793	***	-	-	-	-	-	-	-

***, ** and * significant at p < 0.001, 0.01 and 0.05 levels; ns = non-significant. GRF = gross return above fertiliser cost.

kharif season in Tamil Nadu. Similar observations were also noticed during the rabi season in Karnataka. NE estimates the attainable yield targets based on robust scientific principles, considers growing environment according to site characteristics and farmers' actual yield while estimating the realistic attainable yield.

Comparison of NE-estimated Yield Responses versus Actual Yield Responses

Yield response to fertiliser application is a function of indigenous nutrient supplying capacity of soil and is determined from soil characteristics (i.e., texture, colour and content of organic matter), historical use of organic inputs (if any), and apparent nutrient balance (for P and K) from the previous crop. The algorithms involved in NE are so rigorous that it captures the required information through logical questions and estimates the yield responses close to the actual yield responses determined through omission plot techniques. The NE-estimated yield responses compared with that of actual yield responses (**Table 1**) showed that N responses estimated with NE were higher by 28, 44 and 11% in Andhra Pradesh, Tamil Nadu and Odisha and lesser by 18% in Karnataka than the actual N response. The NE-estimated P response was higher than the actual P response in Tamil Nadu by 27% and NE-estimated K response was higher than the actual K response in Karnataka and Tamil Nadu by 13 and 12%. In the rest of the regions, NE estimated lower P and K responses than the actual response. Averaged over four states, NE estimated 16% higher N response, 31% lower P_2O_5 response and 29% lower K_2O response over the actual responses observed through omission plot techniques (**Table 1**). The variation in yield response estimated with NE over the actual yield response observed from limited number of omission plot experiments indicated that NE is capable of capturing the temporal variability of nutrient requirement across the seasons along with considering the spatial variability between farmers' fields. Also, NE estimates yield responses based on sound scientific principles even in the absence of soil testing and forms the basis for generating fertiliser recommendations.

Comparison of NE-based Nutrient Recommendation with Farmer Practice

A comparative study of nutrient use between the two nutrient management options (NE and FP) was shown in **Table 2**. During kharif, NE-recommended nutrient use averaged over four states indicated that N, P_2O_5 and K_2O use with NE varied from 106 to 210, 17 to 84, and 18 to 143 kg/ha, with an average of 161, 48, and 61 kg/ha, respectively. The corresponding nutrient use based on FP varied from 136 to 550, 20 to 230, and 0 to 352 kg/ha, with an average of 169, 82, and 100 kg/ha for N, P_2O_5 and K_2O, respectively. On average, the NE-based fertiliser recommendation reduced N, P_2O_5 and K_2O use by 8, 34 and 39 kg/ha indicating 5, 40 and 39% reductions in nutrient use over FP. With the use of NE-based fertiliser recommendation, the lowest N use in FP has increased from 27 to 110 kg/ha in NE, whereas, the maximum N use in FP has decreased from 550 to 210 kg/ha in the NE-based recommendations. This indicates that NE, in addition to suggesting a right rate of nutrients sufficient to meet the attainable yield targets, also helps in optimising nutrient use through appropriate adjustments (increase or decrease) in fertiliser application. Similar observations were also noted for optimising P_2O_5 and K_2O use with NE-based fertiliser recommendations (**Table 2**). The difference between NE and FP for N and P_2O_5 use in Andhra Pradesh, P_2O_5 use in Karnataka, NPK use in Tamil Nadu and N use in Odisha were statistically significant.

The fertiliser application based on NE recommendation during rabi revealed that application of N, P_2O_5 and K_2O across three southern states varied from 110 to 257, 17 to 92, and 22 to 105 kg/ha with an average of 171, 45, and 53 kg/

Odisha farmers expressed satisfaction after visiting the Nutrient Expert® plot.

ha, respectively (**Table 2**). Across all sites, on average, NE reduced N, P_2O_5 and K_2O rates by 27, 33, and 21 kg/ha over FP, resulting in a rate reduction of 14, 40, and 20% of N, P_2O_5 and K_2O use, respectively. NE recommended slightly higher N rates and slightly lower P_2O_5 and K_2O rates during rabi in comparison to the kharif. Nutrient rates generated through NE are based on the estimated yield response to NPK application and NE estimated relatively high N response in rabi season over the kharif season (data not shown). The mean yield response to application of N, P_2O_5 and K_2O during kharif were 3.9, 1.1 and 1 t/ha; whereas, the estimated responses during rabi were 5.2, 0.9 and 1 t/ha, respectively.

NE Use and Improved Yield and Economics of Maize

Data showing the relative performance of NE use over SR and FP for grain yield of maize, fertiliser cost and GRF are given in **Table 3**. Across all sites (n = 117) during the kharif season, NE-based fertiliser use resulted in increased maize yield and economic benefit (i.e., gross return above fertiliser cost or GRF) over FP and SR. Compared to FP, on average it increased yield by 1.1 t/ha and GRF by ₹12,537/ha with a reduction in fertiliser cost (significant only at Karnataka and Tamil Nadu) of ₹1,241/ha. NE-based fertiliser recommendations also increased yield (by 0.9 t/ha) and GRF (by ₹9,844/ha) over SR with a minimal reduction in fertiliser cost (₹-156/ha). NE-based fertiliser recommendations were also tested against FP and SR during the two consecutive rabi seasons (2011-13) at 74 locations in three southern states of Andhra Pradesh, Karnataka and Tamil Nadu. Results revealed that across the three states, grain yield with NE significantly increased by 14 and 6% over FP and SR, respectively (**Table 3**). NE-maize also increased GRF by ₹12,352 and ₹4,430/ha over FP and SR and it reduced the fertiliser cost by ₹2,204 and ₹906/ha over FP and SR, respectively.

Improved maize yields with the use of NE-based fertiliser recommendations could be attributed to the 4R compliant scientific nutrient prescriptions generated by NE, which primarily suggests application of major NPK nutrients using the right fertiliser sources, applied at the right rate and at the right time. NE also suggested application of secondary and micronutrients wherever they were deficient (data not shown) and helped in promoting balanced use of all the essential nutrients in addition to improving yields and optimizing nutrient use. The higher GRF with the use of NE over FP and SR could be attributed to higher maize yields and the associated reduction in fertiliser cost observed with NE-based recommendations. NE provides nutrient recommendations tailored to location-specific conditions. In contrast to SR, which gives one recommendation per state (e.g., 150 kg N, 75 kg P_2O_5, and 75 kg K_2O/ha in Andhra Pradesh), NE recommends a range of N, P_2O_5 and K_2O application rates within a region depending on attainable yield and expected responses to fertiliser at an individual farmer's field. Thus, fertiliser N, P_2O_5 and K_2O requirements determined by NE, varied among fields or locations, proved to be critical in improving the yield and economics of maize farmers in the region. In effect, use of the NE actually increased yields and profit, while reducing economic risk to the farmers, simply by providing scientific direction in the most appropriate use of fertilisers with each individual field.

Summary

NE field-specific fertiliser recommendations, demonstrated in the southern region, increased yield and economic benefits through optimised application of nutrients that takes into account variations in the growing environment, affected by climate, soil type, nutrient availability, cropping system, and crop management practices. It estimated the major nutrient requirement for a practical and challenging yield target and the tool also provided secondary and micronutrient recommendations wherever these nutrients are limiting. Besides providing location specific nutrient recommendations, the tool has options to tailor recommendations, based on resource availability to the farmers. BCSA

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