Nutrient Expert™: A Tool to Optimise Nutrient Use and Improve Productivity of Maize

By T. Satyanarayana, K. Majumdar, M. Pampolino, A.M. Johnston, M.L. Jat, P. Kuchanur, D. Sreelatha, J.C. Sekhar, Y. Kumar, R. Maheswaran, R. Karthikeyan, A. Velayutahm, Ga. Dheebakaran, N. Sakthivel, S. Vallalkannan, C. Bharathi, T. Sherene, S. Suganya, P. Janaki, R. Baskar, T.H. Ranjith, D. Shivamurthy, Y.R. Aladakatti, D. Chiplonkar, R. Gupta, D.P. Biradar, S. Jeyaraman, and S.G. Patil.

Nutrient Expert (NE)-based field-specific fertiliser recommendations offered solutions to the farmers of southern India for better nutrient use in maize under the current scenario of escalating fertiliser prices. Results from validation trials, comparing NE-based recommendations with FP and SR in 82 farmer fields of southern India, demonstrated the utility of the decision support system tool in improving the yield and profitability of maize farmers in the region.

Maize, a crop of worldwide economic importance, together with rice and wheat, provides approximately 30% of the food calories to more than 4.5 billion people in 94 developing countries, and the demand for maize in these countries is expected to double by 2050. In India, maize is considered as the third most important food crop among the cereals and contributes to nearly 9% of the national food basket (Dass et al., 2012). The annual maize production of the country is about 21.7 million t with an annual growth rate of 3 to 4 % (ASG, 2011). Maize yields in India need to be increased significantly to sustain this growth rate and there is a need to further increase the productivity of maize to efficiently meet India's growing food, feed and industrial needs.

In Southern India, farmers are substituting maize for traditional crops such as rice wherever there is a drop in the water table due to over use of water by the rice crop. Maize is considered as a viable option for diversifying agricultural production, owing to its adaptability in multiple seasons under different ecologies. Recently, maize is gaining popularity as a rice-maize cropping system in the state of Andhra Pradesh, replacing the second rice crop in the existing rice-rice or rice-rice-pulse cropping systems due to water scarcity in rice and incidence of diseases in pulses. Similarly, maize is also becoming an important crop in Tamil Nadu and Karnataka due to its higher productivity and profitability, and is grown either as a sole crop in *Kharif* or in sequence after rice during the *Rabi* season. In the emerging rice-maize system in the region, the maize crop following rice is mostly grown under no-till conditions due to lack of time between crops for preparatory cultivation. Farmers in the region lack knowledge about managing nutrients within this highly demanding cereal system and are often applying inadequate and imbalanced rates. This has resulted in uncertain system yields and raised doubts on long-term sustainability. Further, conservation tillage systems pose greater challenges for farmers due to lack of information on efficient nutrient management strategies under these systems.

The average maize yields in southern India are much lower than reported attainable yields and one of the key factors responsible for low yields is inadequate and improper fertilisation. Current fertiliser use is quite imbalanced to achieve maximum economic yields for new maize hybrids used by farmers. Moreover, nutrient requirement varies from field-to-field due to high variability in soil fertility across farmer fields, and single homogenous and sub-optimal official state recommendations may not be very useful in improving maize yields. Also, the current scenario of escalating prices of fertilisers demands solutions for optimised use of nutrients. Thus, there is ample opportunity to improve maize yields through the right use of nutrients. Nutrient Expert, a new, nutrient decision support system (DSS) based on the principles of site-specific nutrient management (SSNM), offers solutions for providing field-specific fertiliser recommendations to improve the yield and economics of maize growing famers in the region.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; Zn = zinc; Mn = manganese; Fe = iron; B = boron; CO_2 = carbon dioxide; FP = farmer practice; SR = state recommendation.

IPNI, CIMMYT, and UAS Raichur staff visiting the Nutrient Expert validation trials at CSISA hub site in Bheemarayanagudi, Karnataka.

While generating recommendations, NE considers yield response and targeted agronomic efficiency in addition to quantifying the contribution of nutrients from indigenous sources. It also considers other important factors affecting nutrient management recommendations in a particular location and enables crop advisors to provide farmers with fertiliser 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 (Pampolino et al. 2012a). Currently, IPNI has developed NE for different geographies of Asia and Africa. The objective of this paper is to evaluate and compare the performance of NE-based fertiliser recommendation with FP and SR, and demonstrate the merits of using NE in maize by presenting results from on-farm evaluation trials conducted in southern India.

Field evaluation of NE maize was conducted in varying maize growing environments, under rainfed and assured irrigated conditions, at 82 major maize growing sites in southern India. The study area covered Karimnagar, Ranga Reddy, Guntur, and West Godavari districts of Andhra Pradesh; Dharwad, Gulbarga, Yadgir, and Bangalore districts of Karnataka; and Perambalur, Dindigul, Thanjavur, and Coimbatore districts of Tamil Nadu during the *Kharif* and *Rabi* seasons of 2011-12. The experiments were carried out by the International Plant Nutrition Institute (IPNI) in collaboration with the Interna-

Table 1. Comparison of nutrient use across three nutrient management options.

Parameter	Unit	Kharif 2011 (Monsoon season) FP[1]	SR	NE	NE-FP		Rabi 2011-12 (Winter season) FP	SR	NE	NE-FP	
		Andhra Pradesh (n = 8)					**Andhra Pradesh (n = 27)**				
Fertilizer N	kg/ha	121-550 (229)	180	110-210 (148)	-82	ns	140-855 (288)	200	150-230 (203)	-85	**
Fertilizer P_2O_5	kg/ha	38-230 (87)	60	17-64 (37)	-51	ns	25-753 (153)	60	27-71 (54)	-99	***
Fertilizer K_2O	kg/ha	42-150 (74)	50	18-55 (38)	-35	ns	0-168 (68)	50	51-104 (74)	6	ns
		Karnataka (n = 12)					**Karnataka (n = 11)**				
Fertilizer N	kg/ha	80-174 (125)	150	110-230 (152)	27	*	80-218 (130)	150	110-190 (154)	24	ns
Fertilizer P_2O_5	kg/ha	58-148 (113)	75	20-81 (38)	-75	***	58-115 (77)	75	17-64 (42)	-35	***
Fertilizer K_2O	kg/ha	23-110 (67)	75	22-104 (62)	-5	ns	0-75 (29)	75	29-81 (57)	28	*
		Tamil Nadu (n = 12)					**Tamil Nadu (n = 12)**				
Fertilizer N	kg/ha	147-332 (225)	135	130-210 (182)	-43	*	95-360 (210)	210	130-150 (148)	-62	*
Fertilizer P_2O_5	kg/ha	48-79 (67)	63	27-47 (42)	-25	***	25-258 (111)	70	28-47 (39)	-72	*
Fertilizer K_2O	kg/ha	48-352 (201)	50	29-55 (43)	-158	***	50-270 (128)	65	22-59 (31)	-97	**
		Southern India (n = 32)					**Southern India (n = 50)**				
Fertilizer N	kg/ha	80-550 (193)	-	110-230 (161)	-32	ns	80-855 (209)	210	110-230 (168)	-41	**
Fertilizer P_2O_5	kg/ha	38-230 (89)	-	17-81 (39)	-50	***	25-753 (114)	70	17-71 (45)	-69	***
Fertilizer K_2O	kg/ha	23-352 (114)	-	18-104 (48)	-66	***	0-270 (75)	65	22-104 (54)	-21	ns

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

tional Maize and Wheat Improvement Centre (CIMMYT), the Directorate of Maize Research (DMR), state agricultural universities (UAS Dharwad, UAS Raichur, and TNAU Coimbatore), Industry (Canpotex, Coromandel International Ltd., and Bayer BioScience Ltd.), and farmers. A survey was carried out in all locations prior to initiation of experiments and the current maize yields along with the nutrient application rates were recorded to understand the actual yields realised by the farmers. Nutrient Expert was used to provide field-specific fertiliser recommendations for an attainable yield target at each site, which was tested against fertiliser recommendations followed in SR and FP. Conventional (CT) and conservation tillage (CA) were considered as the options of crop establishment. There were 26 sites under CT and 6 sites under CA during the *Kharif* season, whereas, 31 sites had no-till (CA) and the remaining 29 sites were grown under CT during the *Rabi* season. Performance of NE was evaluated in terms of fertiliser use, maize grain yield, fertiliser cost, and gross returns above fertiliser cost (GRF).

Comparison of Fertiliser Use (FP vs. SR vs. NE)

A survey conducted on fertiliser use revealed that the nutrient use by maize growing farmers is highly skewed in southern India (**Table 1**). In *Kharif*, nutrient use data in three southern states indicated that N, P_2O_5, and K_2O fertiliser use in FP varied from 80 to 550, 38 to 230, and 23 to 352 kg/ha, with an average of 193, 89, and 114 kg/ha, respectively. The corresponding NPK use based on NE recommendations varied from 110 to 230, 17 to 81, and 18 to 104 kg/ha, with an average of 161, 39, and 48 kg/ha, respectively. The NE-based fertiliser recommendations reduced N, P_2O_5, and K_2O use by 32, 50, 66 kg/ha indicating 17, 56, and 58% reductions in fertiliser use over FP. Close observation of data in **Table 1** for nutrient use in *Kharif* further revealed that the lowest N use in FP has increased from 80 to 110 kg/ha in NE, whereas, the maximum N use in FP has decreased from 550 to 230 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 reductions in fertiliser application. Similar observations were also noted for optimising P_2O_5 and K_2O use with NE-based fertiliser recommendations (**Table 1**). The difference between NE and FP for N and P_2O_5 use in Karnataka and NPK use in Tamil Nadu were statistically significant.

NE-based fertiliser application during *Rabi* season re-

Table 2. Performance of NE-based recommendations for yield and economics of maize in southern India.

Parameter	Unit	---------- Kharif 2011 (Monsoon season) ----------					---------- Rabi 2011-12 (Winter season) ----------				
		FP[2]	SR	NE	NE-FP		FP	SR	NE	NE-FP	
		Andhra Pradesh (n = 8)					Andhra Pradesh (n = 27)				
Grain Yield	kg/ha	7,254	7,569	8,007	753	*	8,568	8,635	9,699	1,131	***
Fertilizer Cost	Rs/ha	6,820	4,991	3,580	-3,240	ns	9,509	5,220	5,459	-4,050	**
GRF[1]	Rs/ha	65,586	72,114	75,211	9,625	*	76,167	80,894	91,770	15,603	***
		Karnataka (n = 12)					Karnataka (n = 11)				
Grain Yield	kg/ha	5,214	5,907	7,026	1,812	***	8,831	9,385	10,215	1,384	**
Fertilizer Cost	Rs/ha	6,335	5,543	4,112	-2,223	**	4,522	5,543	4,183	-339	ns
GRF	Rs/ha	45,809	54,958	64,716	18,907	***	83,784	89,671	96,602	12,818	***
		Tamil Nadu (n = 12)					Tamil Nadu (n = 12)				
Grain Yield	kg/ha	8,154	7,622	8,774	620	**	6,550	7,114	7,405	855	***
Fertilizer Cost	Rs/ha	8,488	4,514	4,232	-4,256	***	8,395	5,960	3,546	-4,849	**
GRF	Rs/ha	73,058	71,988	83,230	10,172	***	57,106	67,595	68,099	10,993	***
		Southern India (n = 32)					Southern India (n = 50)				
Grain Yield	kg/ha	6,874	7,033	7,936	1,062	***	7,983	8,378	9,106	1,123	***
Fertilizer Cost	Rs/ha	7,214	5,016	3,975	-3,239	***	7,475	5,574	4,396	-3,079	***
GRF	Rs/ha	61,484	66,353	74,386	12,902	***	72,352	79,387	85,490	13,138	***

***, **, *significant at $p < 0.001$, 0.01, and 0.05 level; ns = non-significant.
[1]GRF = gross return above fertilizer cost.
[2]FP, SR, and NE = Farmer Practice, State Recommendation, and Nutrient Expert.
Prices (in Rs/kg): Maize = 10.00; N = 11.40; P_2O_5 = 32.2; K_2O = 18.8

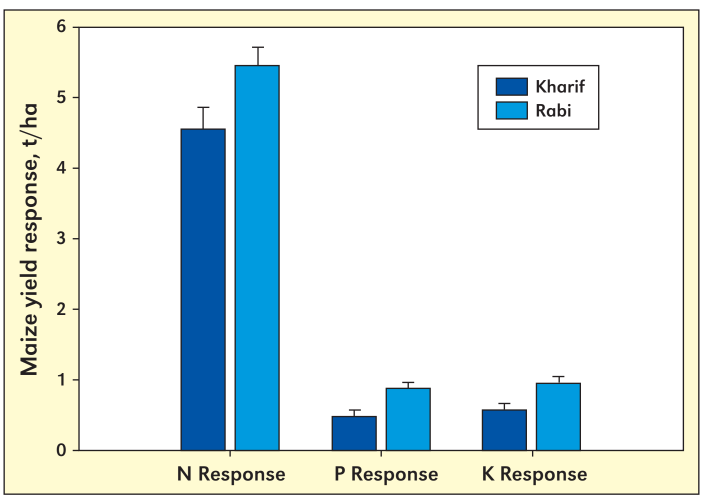

Figure 1. Average maize yield response to NPK application across growing seasons in Southern India (all 82 sites).

vealed that application of N, P_2O_5, and K_2O across the states of southern India varied from 110 to 230, 17 to 71, and 22 to 104 kg/ha with an average of 168, 45, and 54 kg/ha, respectively (**Table 1**). Across all sites, NE-Maize reduced N, P_2O_5, and K_2O rates by 41, 69, and 21 kg/ha over FP, resulting in a rate reduction of 20, 61, and 28% of N, P, and K fertilisers, respectively. NE-maize recommended slightly higher N, P_2O_5, and K_2O rates during *Rabi* in comparison to the *Kharif* season. This is due to the fact that nutrient rates generated through NE are based on the estimated yield response to NPK application and NE estimated relatively high yield responses in *Rabi* season over the *Kharif* season (**Figure 1**). The mean yield response to application of N, P_2O_5, and K_2O during *Kharif* were 4.56, 0.48, and 0.58 t/ha; whereas, the estimated responses during *Rabi* were 5.47, 0.9, and 0.95 t/ha, respectively.

Performance of NE-Maize in Conventional vs. Conservation Tillage Areas

Conservation tillage practices are gaining importance in southern India. The study area had 6 out of 32 locations in *Kharif* and 31 out of 52 locations in *Rabi* season with CA where maize did not receive preparatory cultivation and was grown under no-till conditions. Nutrient recommendations from NE-Maize were tested against FP and SR under CT and CA during both the growing seasons. Across seasons, NE recorded higher grain yield in CA (9.3 t/ha) in comparison to CT (8.4 t/ha) and the magnitude of yield increase over CT (**Figure 2**) was higher in *Kharif* (20%) than in the *Rabi* (3%) season, respectively. Several researchers (Moschler and Martens, 1975; Wells, 1984) comparing CT and no-till production systems suggested that more efficient utilisation of fertiliser with no-till production gave higher yields in CA. Pampolino et al. (2012b) also reported similar observations while evaluating NE-Wheat in different tillage options under varied growing environments.

NE-based Fertiliser Recommendations Improving Yield and Economics of Maize

Data pertaining to relative performance of NE over SR and FP for grain yield of maize, fertiliser cost, and GRF are given in **Table 2**. Across all sites (n=32) during the *Kharif* season, NE-Maize increased yield and economic benefit (i.e. gross return above fertilizer costs or GRF) over FP and SR (**Table 2**). Compared to FP, on average it increased yield by 1.06 t/ha and GRF by 12,902 INR/ha with a significant reduction in fertilizer cost of 3,239 INR/ha. Recommendations from NE-Maize also increased yield (by 0.9 t/ha) and GRF (by 8,033 INR/ha) over SR with a moderate reduction in fertilizer cost

(-1,041 INR/ha). NE-based fertiliser recommendations were also tested against FP and SR during *Rabi* season of 2011-12. Across the three southern states during *Rabi* season (n=50), grain yield with NE was significantly increased by 14 and 9% over FP and SR, respectively (**Table 2**). NE-maize also increased GRF by 13,138 and 6,103 INR/ha over FP and SR and it reduced the fertiliser cost by 3,079 and 1,178 INR/ha over FP and SR, respectively.

Yield improvement with NE-based fertiliser recommendation could primarily be attributed to a balanced application of nutrients than increasing the nutrient rates. The NE program recommended application of secondary and micronutrients especially S, Zn, Mn, Fe, and B at 48 out of 82 locations in the study area (data not shown). Also, farmers in 11 out of 82 locations did not apply K fertilisers under FP, whereas, NE-based recommendations bridged such gaps and provided optimum rates of K recommendations in the respective fertiliser schedules. This clearly explains how NE helped in promoting balanced use of all the essential nutrients thereby improving yields and optimising nutrient use in the maize growing areas of Southern India.

The higher GRF when using NE than in FP and SR justifies the substantial reduction in fertiliser cost with NE-based recommendations. NE-Maize provides nutrient recommendations that are 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 per ha in Andhra Pradesh), NE recommends a range of N, P_2O_5, and K_2O application rates within a site depending on attainable yield and expected responses to fertiliser at individual farmers' fields. Further, the estimated maize yield response by NE to application of N, P_2O_5 and K_2O fertilisers across the growing seasons varied from 2 to 8, 0 to 1.8, and 0 to 2 t/ha with a mean response of 5.02, 0.69, and 0.77 t/ha (data not shown), and captured the temporal variability of nutrient requirement between seasons along with the spatial variability between farmers'. The varied yield response to N, P, and K application suggests that single homogenous state recommendations (**Table 1**) may become inadequate for improving maize yields in the region. 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 farmer, simply by providing some direction in the most appropriate fertilizer rate.

Summary

Maize, owing to its efficient utilisation of radiant energy and fixation of CO_2 from the atmosphere, is considered as one of the major high yielding crops of the world. This versatile crop has wider adaptability to varied growing seasons and diverse ecologies and can address some of the food security issues of the nation. Despite maize being grown predominantly as a rainfed crop, its productivity is more than other cereals like rice and wheat, which are grown under assured irrigated/favorable rainfed conditions in south India. However, maize is an exhaustive feeder of nutrients and balanced and adequate application of fertiliser nutrients is the key not only for improving the current yield levels but also for sustaining the profitability of maize growing farmers in the country. Nutrient Expert-based field specific fertiliser recommendations, demonstrated in southern India, increased yield and economic benefits through balanced application of nutrients. This DSS was able to capture the inherent differences between conventional and conservation practices of crop management, and NE-based fertiliser recommendations generated on the principles of SSNM performed better than FP and SR for maize. Besides providing location-specific nutrient recommendations rapidly, the tool has options to tailor recommendations based on resource availability to the farmers. There is a need to rapidly disseminate NE-based fertiliser recommendations for maize through extension agents and we anticipate that a user friendly tool like NE-Maize, with it's robust estimation of site-specific nutrient recommendations, will be attractive to extension specialists working with millions of small holder farmers in the intensively cultivated maize areas in southern India. BC-SA

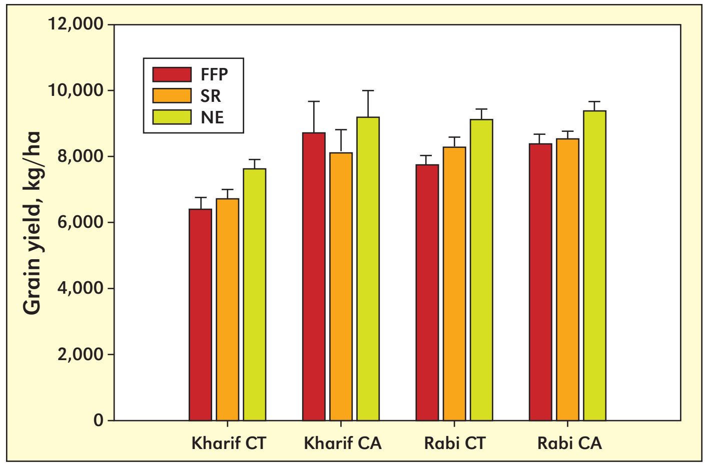

Figure 2. Effect of nutrient management options under varied seasons and crop establishments on grain yield of maize.

Dr. Satyanarayana is Deputy Director, IPNI South Asia Program; e-mail: tsatya@ipni.net; Dr. Majumdar is Director, IPNI South Asia Program; Dr. Pampolino is Agronomist at IPNI Southeast Asia Program; Dr. Johnston is Vice President and IPNI Asia and Africa Program Coordinator; Dr. Jat is Cropping System Agronomist, International Maize and Wheat Improvement Center (CIMMYT); Dr. Kuchanur, Associate Professor, Mr. Ranjith, M.Sc. student, and Dr. Patil, Director of Education, are with UAS Raichur; Mr. Kumar is CIMMYT Agronomist; Dr. Sreelatha is Scientist at Maize Research Institute, ANGRAU Hyderabad; Dr. Sekhar is Principal Scientist at Directorate of Maize Research; Dr. Velayutham, Professor, Dr. Dheebakaran, Dr. Sakthivel, Dr. Vallalkannan, Dr. Bharathi, Dr. Sherene, Dr. Suganya, Dr. Janaki, and Dr. Baskar are Assistant Professors, and Dr. S. Jeyaraman, Director of Crop Management, are with TNAU, Coimbatore; Mr. Shivamurthy, Ph.D. student, Dr. Aladakatti, Senior Scientist, and Dr. Biradar, Professor, are with UAS Dharwad; Mr. Maheswaran, Manager and Mr. Karthikeyan, Senior Manager, are with Coromandel International Ltd., Mr. Chiplonkar, Corn Breeder and Dr. Rajan, Lead Breeder, are with Bayer BioScience Pvt. Ltd.

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