RESEARCH ARTICLE

Nutrient Expert as Decision Supporting Tool to Reduce Nitrate Toxicity in Cereal Crops

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An enormous portion of nutrient (crop residue) is taken out from soil on account of its competitive use and considerably less residue returning to soil leading to negative balance, prompts lower crop productivity, poor economic return and low nutrient use efficiency prompting large environmental footprint. In many situations, blanket fertilizer application resulted in under-fertilization, while in others, it resulted in over-fertilization. Near the Indo Gangetic Plains (IGP), farming communities frequently apply greater doses of nutrients, particularly nitrogen (N) and phosphorus (P), but largely ignore the optimal dosages of potassium and other secondary and micronutrients. Such unbalanced and insufficient nutrient use can reduce nutrient use efficiency and profitability, as well as increasing environmental risks connected with nutrient loss through emission or leaching. Decision support tools (DST) are being utilized increasingly to help farmers implement better fertilizer management methods in their crops. Nutrient Expert for Wheat and Maize, a recently developed DST, integrated on-farm research data into a simple delivery system that allows growers to quickly adopt nutrient management site specific for their own fields. The decision support tool was created in 2010-11 as a simple, interactive computer-based tool that can quickly offer nutrient recommendations for farmers' fields, independent of weather with no soil testing required. This tool is useful in determining the nutrient balance replenished in the cropping system based on fertilizer/manure and yield provided in the previous harvest, as well as measure the attainable yield for any field based on growing conditions. These were all combined to provide a location-specific nutrient prescription for cereals by estimating expected N, P, and potassium (K) responses in the concerned field. Nutrient Expert has the ability to move the focus away from conventional agriculture and toward farming that is more sustainable, efficient, and productive.

Introduction

The present world population of 7.6 billion people will increase to 8.6 billion in 2030, 9.8 billion in 2050, and 11.2 billion in 2100, according to the United Nations (2017). With roughly 83 million individuals added to the world's population each year, the population growth trend is anticipated to continue. [**1**]. Global cereal consumption is anticipated to reach 2811 million tonnes in 2021/22, up 2.7 million tonnes from September and 49 million tonnes (1.8%) more than in 2020/21 and marking a new record high [**2**]. This rising demand for cereals to feed the world's population will be fulfilled not just by expanding cultivated land but also by intensifying output, particularly of rice, wheat, and maize. Extra efforts have to be made to get higher output per unit area with land as a limiting factor. Productivity enhancement is required particularly in the part of the world basically dominated by the small holding farming systems compared to the large holding farming system. The challenge in global as well as regional aspect for increasing production is food security as there is a need to produce more from much lesser area because of the other competitive use of land. Several other challenges include the declining productivity of the land, nutrient acquisition by more efficient cultivars which tend to decrease the nutrient reserve of the soil and deplete native soil fertility. Considering the frontier practice for better productivity, adequate plant nutrition is a key in increasing the crop yield, closing the yield gaps and attaining sustainable intensification.

By combining and harmonizing the use of organic, mineral, and biofertilizer nutrient resources to meet the concurrent needs of food production, economic, environmental, and social viability, an integrated plant nutrition system (IPNS) or integrated nutrient management (INM) is allowing better adaptation of soil fertility management and plant nutrition to site characteristics in farming systems. [**3**]. So, it's necessary to have a scientific based fertilizer recommendation as fertilizer application practice in smallholding agriculture is often sub-optimal and unbalanced. The soil fertility varies over short distances and yields are generally low even with high cropping intensities.

Fate of nitrogen

Nitrogen in plants

The availability and uptake of macro and micronutrients in the soil determine the plant's nutrition. Nitrogen (N) is a significant mineral element utilized in agricultural fertilization and is important for the development of leaf area. Because there are more and larger leaves, N helps to promote leaf area (AF) and leaf area index (LAI). It enhances the green color of the leaves and is a constituent of vital biological components such as amino acids, proteins, and nucleic acids. It also regulates P, K and other nutrients, enhances crop succulence, and promotes photosynthesis by raising chlorophyll levels in the plant. N shortage results in weak stems and excessive dosages. As a result of the lush foliage and succulents, ideal circumstances for the development of many illnesses exist [**4**].

Issue with conventional mode of nitrogen application

Blanket application is a commercial practice that involves fertilizer application doses at specific growth stages at predetermined times.

There is a risk of over and under fertilization when using nitrogen.

Nitrogen has low nutrient use efficiency. There is an increase in cost of cultivation.

By matching fertilizer application time to plant need, the real-time nitrogen management strategy can assist boost nitrogen use efficiency.

Nutrient toxicity

In 2018-19, the average per hectare fertilizer use (N+P+K) in India was 133.1 kg/ha [**5**]. Imbalanced and insufficient nutrient usage can reduce nutrient use efficiency and profitability while also increasing environmental concerns from unutilized nutrient loss through emission or leaching. So, what is the solution?

Smart agriculture

The use of technologies such as the Internet of Things, sensors, positioning systems, robots, and artificial intelligence on your farm is referred to as smart agriculture. The ultimate goal is to improve crop quality and quantity while reducing the amount of human work required. Precision irrigation and plant nutrition, greenhouse climate management and control, sensor software platforms, location systems such as GPS and satellites, communication systems, robots, analytics and optimization platforms are all examples of smart agriculture technologies.

Site specific nutrient management

Site specific nutrient management (SSNM) is the process of applying nutrients to the soil through time and space in order to fit the needs of crops through four key principles known as “4 R”. The four key principles or 4R's are Right product, Right rate, Right time and Right place [**6**].

Site-specific nutrient management (SSNM) is a low-tech, plant-needs-based technique for efficiently supplying N, P and K. It allows farmers to dynamically adjust fertilizer use to bridge the gap between high-yielding crops' nutrient needs and nutrient supply from natural indigenous sources like soil, manures, crop wastes and irrigation water etc. The purpose of the SSNM technique is to apply nutrients at the right rates and at the right times in order to increase rice yields and crop nutrient efficiency. It does not have a defined goal of reducing or increasing fertilizer use. It is based on scientific ideas that have been developed over the course of nearly a decade of on-farm study in Asia [**7**].

Nutrient expert decision support tool

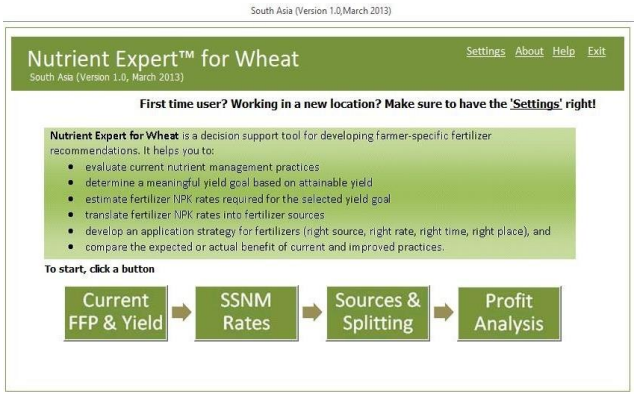
The International Plant Nutrition Institute, in association with CIMMYT and other national agricultural research and extension organizations, created Nutrient Expert software to provide fertilizer recommendations to farmers in the absence of soil testing. It is a computerized decision supporting tool that facilitates farmers in recommending fertilizers using the principle of 4Rs of nutrient stewardship and site specific nutrient management into a fertilizer recommendation. Nutrient Expert has versions for both PCs and Android devices (e.g., tablet, smartphone). NE considers the most essential aspects that influence nutrient management recommendations and employs a methodical approach to data collection, which is critical for creating a location-specific recommendation. However, unlike many complex nutrient decision assistance programmes, NE does not require a lot of data or highly precise information, which could overwhelm the user. NE combines all of the different stages and principles of SSNM into a user-friendly programme aimed at agricultural advisers, particularly non-technical users like extension agents and industrial agronomists of developing countries. Many governmental and corporate agricultural advisors lack the infrastructure and data needed to conduct complicated models. Users can get the information required from their indigenous experience, local farmers' knowledge, and agricultural practices using NE. NE not only sufficiently use experimental data, but also use existing site knowledge to estimate proper SSNM values. Nutrient omission studies in farmers' fields are routinely used in determining SSNM principles. NE allows farm consultants to generate fertilizer recommendations for a specific site without having to rely on field trial data because parameters may be approximated using proxy data. [**8**]

It is a global project of IPNI participated by IPNI programs in Asia and Africa and their local partners. The development of NE started from Maize in South East Asia and expanded to other geographic regions and crops. At present, there are 14 field validated versions and 3 versions under field validation covering a total of 15 countries. The major NE are NE-Maize, NE-Wheat and NE-Rice. It has

been especially beneficial in situations where soil testing infrastructure is lacking, expensive, or not available in a timely manner for diverse cropping systems. Developing a fertilizer recommendation is knowledge intensive as many parameters are to be taken care of like which fertilizer to apply, how much to apply, when to apply, how and where to apply and what is the budget. NE helps to frame these parameters within a system and provide advantageous fertilizer recommendations. Different NE software can be downloaded from the official IPNI website [**9**].

How to use NE: NE consists of 5 modules

- Current FFP & Yield module included questions related to the current yield and fertilizer management practice of the farmer.
- SSNM Rates module estimates expected yield responses to NP and K and generates NPK recommendations.
- Source and Splitting module generates fertilizer recommendation
- Profit Analysis module provides a gross profit analysis [**9**].



How can a farmer get a copy of the recommendation for his field?

The recommendation and other outputs/reports can be saved (html or PDF) and printed. It can be sent through email, or a short version of the recommendation can be sent as text message (from Android device).

Case *study*

Improving wheat yield and farm profitability through Nutrient Expert in Mewat (Haryana)

In Mewat, Haryana the implementation of NE based fertilizer recommendation was made on Wheat crop for two consecutive seasons in 2012-13 and 2013-14. A total of 40 and 60 farmer's field were used. The farmers belonged to 10 villages of the region. Fertilizer costs increased considerably in the NE treatment compared to the FFP treatment due to higher K application. Due to the enhanced wheat yield of nearly 1.5 t/ha, the gross return over fertilizer cost (GRF) in the NE treatment was much higher than the existing farmers' practice (17,247/ha). The overall results reflected that NE recommendations can substantially increase yields as well as profitability compared to existing practices. NE's ability to create a field-specific fertilizer prescription without soil testing is a big step toward giving science-based fertilizer recommendations to a substantial segment of smallholder farmers who lack access to soil testing. The findings revealed that boosting wheat yields in Mewat's water-stressed region requires an appropriate and balanced use of NPK. [**10**].

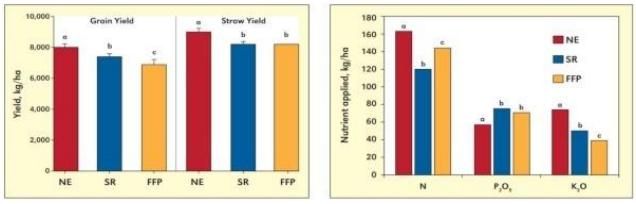
Table 1. Comparison of farmers' fertilizer practice (FFP) with Nutrient Expert (NE) for wheat across all sites and years.

Parameter	FFP	NE	NE-FFP
Grain yield (kg/ha)	3,773	5,226	1,453
N (kg/ha)	117	123	6
P_2O_5 (kg/ha)	54	62	8
K_2O (kg/ha)	9	83	83
Cost of fertilizer (Rs/ha)	4,911	10,190	5,279
GRF (Rs/ha)	53,566	70,813	17,247

Results reflected that NE recommendations can substantially increase yields as well as profitability compared to existing practices [**10**].

Balanced fertilizer use through NE helps in improving maize yield in Bihar

The performance of Nutrient Expert (NE) in Bihar State was evaluated by comparing its results to the SR and FFP. In 17 farmers' fields of five districts (Samastipur, Patna, Begusarai, Jamui and Purnia) in 2011 and 2012, these on-farm tests with winter maize looked at grain yield, economic returns, and NPK fertilizer use. The size of each treatment plot was at least 100 m2. A consistent application of 120-60-40 kg N-P_2O_5-K_2O/ha was used in the SR treatment. Hybrid maize cultivars with yield potentials of more than 5 t/ha were chosen by farmers. The seed rate was chosen for all treatments to keep the planting density between 65,000 and 85,000 plants per hectare. N application ranged between 130 to 190 kg/ha, P_2O_5 application ranged between 44 to 64 kg/ha and K_2O application ranged between 55 to 105 kg/ha according to guidelines of NE, with an average of 163-57-74 kg N-P_2O_5-K_2O/ha. When NE was compared to FFP, the nutrient application rate ranges narrowed. Grain yield and total biomass output were considerably higher in NE-based fertilizer recommendation plots. (Figure 1.1). The average grain yields in the NE, SR, and FFP plots were 8, 7.4 t/ha, demonstrating a 10 to 15% increase in maize grain production when using NE. This reflected that NE could better handle variation in growing conditions in Bihar, implying that it could be a viable technique for site-specific fertilizer management. [**11**].



(a) (b)

Fig. 1. (a) Grain yield and Straw yield comparison between NE, SE and FFP. (b) Average N, P205 and K2o applied in NE, SR and FFP [11] Nutrient Expert enhances crop yields, increases farmer revenue, and minimizes greenhouse gas emissions.

In agriculture, the key mitigation measures include decreasing excess nutrient application and adopting balanced fertilizer. In the Indo-Gangetic Plains (IGP) of India, side-by-side comparison tests with farmers' fertilization practices (FFP) were conducted to evaluate Nutrient Expert (NE) in rice and wheat crops. It was discovered that using NE-based fertilizer management rather of FFP can reduce GWP by about 2.5 percent in rice and between 12 and 20% in wheat. Implementing the NE-based fertilizer recommendation enhanced crop output and farm revenue for more than 80% of the participating farmers. There was also improvement in crop yield [**12**].

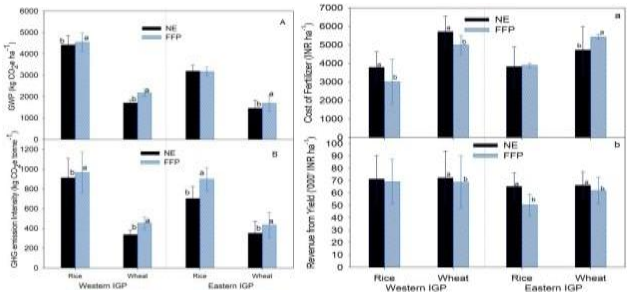


Fig. 2. Fertilizer cost (a) and revenue generated from yield (b) in rice and wheat production under FFP and NE in the study areas, and total global warming potential (A) and emission intensity (B) from rice and production of wheat under Farmers' Fertilizer Practice (FFP) and Nutrient Expert (NE) in the study regions.

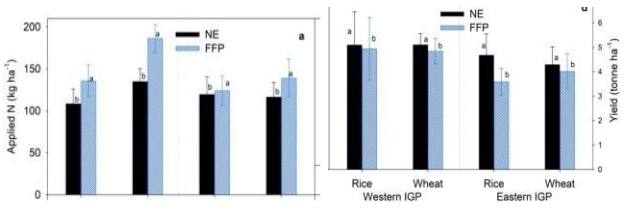


Fig. 3. Nitrogen rate and grain yield from rice and wheat in the study areas under Nutrient Expert (NE) and Farmers' Fertilizer Practices (FFP).

Effect on grain yield, straw yield, biological yield and harvest index in Pantnagar through different treatment

Balance fertilizer (NPK) application is very important for proper growth and development of crop. Among precision nitrogen management techniques, Nutrient Expert has shown potential to get more yields in wheat crop and gave statistically at par results in terms of grain yield and other few yield parameters with 100% RDF [**13**].

Table 2. Grain yield, straw yield, biological yield, and harvest index were compared between different treatments and NE.

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (q/ha)
Absolute control	24.5	46.6	71.1	34.4
50% N	43.2	76.9	120.1	36.0
100% N	47.0	95.9	142.9	32.9
100% RDF	51.3	96.6	147.9	34.9
Nutrient Expert	51.0	95.9	146.9	34.8

Source: Kapri *et al.* [13]

Conclusion

Nutrient Expert is proving to be an ideal method for creating fertilizer recommendations and determine if an adequate nutrient supply exists to permit healthy crop growth. Most Indian farmers, on the other hand, are oblivious to how to manage nutrients in their nutrient-dense cereal systems. NE regularly outperformed the other options in a variety of settings (farmers' field practice or state recommendations). Nutrient Expert has several advantages that have proven it to be a good decision support tool, including:

- It is cost-effective for precision nutrient management, produces less pollution, and has a good impact on plants and soil.
- It is simple to use and does not require any labour or technical skills.
- Using site-specific strategies to optimize nutrient management would increase yield, nutrient usage efficiency, and cereal production profitability.
- Inputs, fertilization processes, environmental circumstances, yield responses to N, P, and K fertilizers, soil fertility metrics, past crop history, and the usage of organic inputs, among other factors, should all be well-understood by the farmer.

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