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Research Article

Nutrient Expert Model: Bridging the Gap between Fertilizer Application and Enhanced Wheat Yield

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ABSTRACT

Cereals are the main staple food of many Asian countries including Pakistan, so their demand is increasing day by day. Use of high cost fertilizers in order to attain the required production levels has become a compulsion for farmers. Under such a scenario achieving higher productivity with minimum input cost is the main goal of today's farming community. In order to find out the possible way to obtain maximum return from the soil with the lowest cost, field experiments were conducted to test the IPNI-nutrient expert model for wheat on farmers' fields during the year 2017 to 2020 in different climatic zones of Punjab, Pakistan. The experiment was conducted in Randomized Complete Block Design (RCBD). There were five treatments including control (no fertilizer), Farmer Practice (FP), NPK at half and full recommended dosages and Nutrient Expert dose (NE) with three replications. The results ascertained that the highest wheat grain yield (5084 kg ha⁻¹) was obtained with NE followed by the recommended dose of NPK (4851 kg ha⁻¹) in the cotton zone, however in all other zones the recommended dose of NPK gave the maximum yield followed by NE. In terms of net revenue obtained, NE performed best amongst the treatments applied. The results of the experiment suggested that the use of advanced models (like IPNI nutrient expert model) for site-specific nutrient recommendations can give higher productivity with maximum economic efficiency in comparison to farmers' own conventional practices.

Keywords: Soil, Macronutrients, IPNI, Wheat Productivity, Punjab, Pakistan.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most significant cereal crops globally and serves as the third most consumed staple food in Asia, following rice and maize (FAO, 2023). In Pakistan, wheat occupies approximately 9.17 million hectares, contributing substantially to national food security and rural livelihoods (USDA, 2022). Despite its importance, a considerable yield gap persists between actual farm-level production and the crop's potential. This gap is primarily driven by rapid urbanization, industrial expansion, and suboptimal agronomic practices. Among these, inefficient nutrient management at the farm level is a critical constraint. The unbalanced application of fertilizers, excessive dependence on specific nutrients (particularly nitrogen), limited adoption of high-efficiency



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fertilizers, and significant environmental nutrient losses collectively contribute to reduced crop productivity and hinder efforts to meet the growing food demand Sarma et al., 2024.

Conventional fertilizer recommendations often rely on fixed application rates and schedules for primary macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—without adequately considering the benefit–cost ratio (BCR) of nutrient use. These generalized recommendations are based on the assumption that crop nutrient requirements remain constant across different regions and seasons. However, practically, nutrient demands are influenced by a multitude of factors, including crop growth conditions, soil fertility status, previous cropping systems, irrigation sources, climatic variations, and the historical application of organic amendments such as farmyard manure (FYM). These variables exhibit significant spatial and temporal variability, rendering uniform fertilizer recommendations suboptimal for maximizing crop productivity and economic returns (Timsina et al., 2021).

Site-specific nutrient management (SSNM) uses multi-scale agronomic and environmental information to guide field-specific decisions for managing nitrogen (N), phosphorus (P), and potassium (K). This strategy helps meet the nutrient demands of high-yielding crops without exceeding what the soil can naturally supply (Hasanain et al., 2021). SSNM enables farmers to dynamically adjust fertilizer inputs to close the gap between crop demand and indigenous nutrient availability. The goal is not to simply reduce or increase fertilizer use but to improve timing and dosage to obtain maximize yield and nutrient use efficiency. This precision leads to higher returns on fertilizer investment and promotes more sustainable nutrient management at the farm level (Dahal et al., 2018).

By improving nutrient use efficiency, SSNM helps maintain or enhance yields while reducing input costs. It also contributes to environmental protection by minimizing excess fertilizer application and reducing associated greenhouse gas emissions—by as much as 50% in some cases (Sharma et al., 2022). Tools like Nutrient Expert®, a decision-support system based on SSNM principles, offer practical, ICT-enabled fertilizer recommendations for crops such as wheat, maize, and rice, supporting widespread adoption of SSNM in diverse agroecosystems (Bhatta et al., 2020).

The Nutrient Expert® Wheat model, developed by the International Plant Nutrition Institute (IPNI), is a user-friendly, computer-based tool designed to assist with nutrient management. It calculates the crop's nutrient requirements using the principles of site-specific nutrient management (SSNM). The model's fertilizer recommendation approach is based on yield response and agronomic efficiency (AE). Unlike other decision support systems, Nutrient Expert® uniquely integrates the interactions between nitrogen (N), phosphorus (P), and potassium (K) (Amgain et al., 2021).

The model's method for determining nitrogen requirements involves targeting a specific agronomic efficiency and estimating the yield response to applied nitrogen. For phosphorus and potassium, the system evaluates internal nutrient efficiency, attainable yield estimates, nutrient balances, and yield responses from added nutrients specific to each field (He et al., 2022). Nutrient Expert® recommends fertilizer doses based on the soil's indigenous nutrient supply, ensuring that fertilizer applications are optimized and that excessive nutrient accumulation in the soil is avoided.

The tool has proven effective in rice, maize, and wheat systems in several Asian countries, where it has been shown to outperform traditional farming practices and blanket fertilizer recommendations in terms of both yield and profitability (Kumar et al., 2012; Pampolino et al., 2012; Dutta et al., 2014; Xu et al., 2014). In addition to boosting crop yields, Nutrient Expert® plays a crucial role in addressing the impacts of climate change by reducing greenhouse gas emissions from agricultural fields. Given its success, Nutrient Expert® has been recognized as an effective Information and Communication Technology (ICT) solution for enhancing rural livelihoods, particularly in Asian countries (Fonsah et al., 2018; Kaninda et al., 2015). However, the model is still in the early stages of testing and validation in some regions (Fonsah et al., 2018). The basic objective of this research is to determine the effectiveness of the Nutrient Expert®-Wheat model in the agro-ecological zones of Punjab, Pakistan, so that use of such latest tools may be made common among local farmers with the help of extension workers. As in Pakistan there is dire need of introducing advancement and new technologies in traditional cultivation system The study was conducted to evaluate the impact of nutrient expert based recommendation on wheat productivity and profitability. Specifically, wheat yields and economic returns were computed and compared under precision fertilizer recommendations generated by Nutrient Expert®-Wheat model with those under traditional farmer fertilizer practices. The research also focused on developing and validating a localized SSNM framework and identifying the most effective crop management practices for wheat through on-farm trials across multiple agro-ecological zones in Punjab.

MATERIALS AND METHODS

Climate and Soil Characteristics

These zones mostly fall under semi-arid to arid climate where temperature ranges from 35-45 °C in summer (May to

August) and in winters 5-10 °C (November to January). Most of the rainfall occurs in monsoon season (early July to September). In rice zone the soils are clayey to clay loam, whereas in other zones most of the soils are loam. Rice-wheat cropping system is mostly followed in rice and central zone, in other zones mixed cropping is common practice.

Site selection, and experimental design

Field experiments were conducted at farmers' fields in differing agro-ecological zones of Punjab, Pakistan, from 2017 to 2020. The trials were carried out over three consecutive years and included five fertilizer treatments: control (NPK 0-0-0), farmer's practice, half of the recommended NPK dose, full recommended NPK dose, and the Nutrient Expert®-based recommendation. The field trials were conducted using a randomized complete block design (RCBD) with three replications.

Table 1. List of experimental sites.

Sr. No.	Location	Longitude	Latitude
1	Shahkot	31.610081°	73.507665°
2	Safdarabad	31.653991°	73.529529°
3	Narowal	32.204153°	74.772040°
4	Lahore	31.439746°	74.584994°
5	Hafizabad	32.041631°	73.563890°
6	Gujranwala	32.285758°	74.189046°
7	Gujrat	32.591291°	74.040478°
8	Sahiwal	30.702260°	73.207020°
9	Taxila	33.793572°	72.812864°
10	Attock	33.898713°	72.411787°
11	Mandi Bahau Din	32.432060°	73.775130°
12	Sarghoda	32.085119°	72.563916°
13	Jhang	31.071293°	73.224540°
14	Faisalabad	31.637560°	73.246280°

Table 2: Treatment Plan (nutrients in kg ha⁻¹)

Treatment	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)
Control	0	0	0
Farmer Field Practice*	120	86	38
Half Recommended NPK	80	57	30
Full Recommended NPK	160	114	60
Nutrient Expert Dose	125	79	68

Nutrient Expert®-Wheat recommendations for each farmer in the zones of Punjab through field interviews using structured questionnaires integrated into the NE®-Wheat model. The farmer data was entered into the NE® software, which generated site-specific nutrient recommendations based on nitrogen (N) from urea, phosphorus (P) from diammonium phosphate (DAP), and potassium (K) from sulfate of potash (SOP). The recommended NPK rates varied across farmer fields under both the Farmer Fertilizer Practice (FFP) and the NE-Wheat model, depending on individual management practices; however, only the average values were used for analysis in this experiment.

Soil analysis

Pre-sowing soil samples were collected from each site and analyzed using standard analytical protocols. The initial soil chemical analysis indicated that the majority of the sites had low levels of organic matter and available phosphorus, while soil potassium levels were generally in the adequate range. Available phosphorus was measured on spectrophotometer using Olsen's method (Olsen et al., 1982), and potassium was determined with flame photometer. Soil organic matter was determined by using Walkley and Black (Walkley and Black, 1934) titration method.

Sowing, data collection and analysis

Wheat was sown in the end of November during Rabi season. The crop was monitored closely throughout its growth cycle until harvest in April. The crop was harvested after maturity and yield data from a 3 × 3 m² harvest area was recorded and analyzed statistically using statistix 8.1 software. The data of all years was pooled and analyzed by using analysis of variance technique (ANOVA). Treatment means were compared using the least significant difference (LSD) test at a 5% level of significance. Methods of analysis described by (Gomez and Gomez, 1984)

were used for analyzing statistical variability. The economic analysis of the data was also done to compute and compare the net revenue of different treatments.

Table 3. Pre-sowing soil analyses of experiment sites (2017-18 to 2019-20).

Parameters	2017-18	2018-19	2019-20
EC (dS m ⁻¹)	0.90	1.76	1.01
pH	8.3	7.9	7.9
O.M.%	0.40	0.60	0.57
Available P (ppm)	2.0	5.4	5.1
Extractable K (ppm)	88	117	103

RESULTS AND DISCUSSION

The overall results of three years experiments from 2017-18 to 2019-20 conducted in different zones suggested that recommendation made through nutrient expert caused 8% increase in wheat grain yield when compared to farmer practice. In rice zone 2.8% increase in yield was recorded with nutrient expert dose when compared to farmer practice and 9.5% when compared to half recommended dose of NPK. Similar trend was observed in central zone with 3% increase in yield when compared to farmer practice and 19% when compared with half recommended dose of NPK. However, in cotton zone nutrient expert dose exceeded all treatments giving even 4.8% more yield compared to recommended dose of NPK, 14 and 36% more yield when compared to farmer practice and half recommended dose of NPK respectively. In Barani areas 20% increase in yield was recorded with nutrient expert dose as compared to farmer practice and 38% when compared to half recommended dose of NPK (Table 3).

Year wise analysis of the data also predicted similar trends, giving overall maximum yield (4546 kg ha⁻¹) by recommended dose of NPK, followed by NE (4305 kg ha⁻¹). However in terms of economic profitability and environment friendly nutrient expert based recommendation was proved more beneficial (Table 4). The results of the experimental trials exhibited that use of IPNI-nutrient expert wheat model also gave economic profitability, as highest net revenue (189313 Rs ha⁻¹) was obtained with nutrient expert based recommendation. Although recommended dose of NPK gave highest yield on overall basis but in terms of economic efficiency nutrient expert model seems to be more beneficial generating 3.2% more net revenue as compared to recommended dose of NPK. Similarly giving 4.7% and 6.8% more net revenue when compared to FP and half recommended NPK respectively (Table 5), similar trends were reported by Hasanain et al., 2021.

Results suggested that highest wheat grain yield was observed with recommended dose of NPK followed by nutrient expert dose at all sites. Among all zones nutrient expert dose caused significant increase in wheat grain yield as compare to all other treatments except recommended dose. Yield enhancement by nutrient expert dose may be attributed to sufficient supply of nutrients to plants with minimum nutrient loss making NE more economical as compared to all other treatments. Ping He et al., 2022 mentioned that use of NE gives higher yields, and profitability along with less environmental risks. Similar trends were reported by (Shahi et al., 2018, Kunwar et al. 2019 and Pramanick et al. 2022). Akarsha et al., 2025 reported that use of nutrient expert approach not only improve the productivity of crops but also minimizes the environmental losses by optimizing the fertilizer application, thus achieving the goal of sustainable production system. Bhatta et al. 2020, Sarma et al., 2024, Timsina et al., 2021 also reported similar studies. Use of nutrients expert model also proved beneficial for other crops as reported by Shanyi Sha et al., 2021 the nutrient expert model improved potato yield and quality of tuber. Similarly NE dose also proved significant for increasing rice panicle weight and nitrogen uptake compared to farmer practice reported by Zhuo Xu et al. 2024. (Amgain, et al., 2021) also reported similar studies on rice.

Table 4. Effect of nutrient expert model on wheat grain yield (kg ha⁻¹).

Treatments	Rice Zone	Central Zone	Cotton Zone	Thal Zone	Barani Zone	Overall
T1	1796 e	1600 e	1210 e	926 c	2363 e	1654 e
T2	3890 c	3818 c	4455 c	3481 b	3663 c	3985 c
T3	3581 d	3303 d	3724 d	3407 b	3173 d	3513 d
T4	4491 a	3933 b	4851 b	4000 a	4445 a	4546 a
T5	4047 b	4376 a	5084 a	3593 b	4192 b	4305 b
LSD	97	50	143	297	121	57

Table 5. Effect of nutrient expert model on wheat grain yield (kg ha⁻¹).

Treatments	2017-18 1*(3R)	2018-19 24*(72R)	2019-20 5*(15R)	Overall 30*(90R)
T1 Control	2021 c	1573 e	1966 e	1654 e
T2 Farmer Practice	4038 b	3996 c	3919 c	3985 c
T3 Half recommended NPK	3919 b	3467 d	3649 d	3513 d
T4 Full recommended NPK	4799 a	4541 a	4519 a	4546 a
T5 Nutrient Expert Dose	3985 b	4359 b	4108 b	4305 b
LSD (0.05)	322	63	155	57

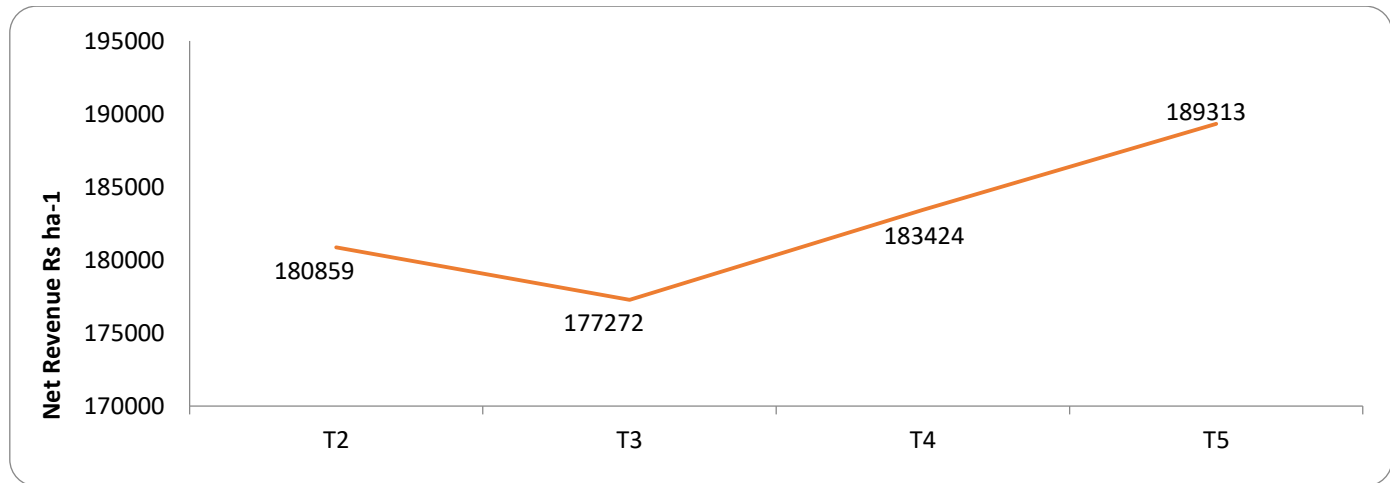


Figure 1. Net revenue trend line.

Table 6. Cost-benefit analysis.

Treatments	Grain Yield (kg ha ⁻¹)	Fertilizer Cost (Rs ha ⁻¹)	Gross Revenue (Rs ha ⁻¹)	Net Revenue (Rs ha ⁻¹)
T ₁ Control	1654	-	114126	-
T ₂ Farmer Practice	3985	94106	274965	180859
T ₃ Half recommended NPK	3513	65125	242397	177272
T ₄ Full recommended NPK	4546	130250	313674	183424
T ₅ Nutrient Expert Dose	4305	107732	297045	189313

CONCLUSION AND RECOMMENDATIONS

Nutrient expert wheat model proved an effective tool for site specific fertilizer recommendation in order to obtain maximum economic efficiency without compromising on crop yield. Therefore, there is a need to develop awareness among farming community about latest technology advancements and bringing them into practice in order to get maximum returns with minimum available inputs.

AUTHOR CONTRIBUTIONS

All authors contributed equally.

COMPETING OF INTEREST

The authors declare no competing interests.

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