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Economic Assessment of Adopting Nutrient Expert® Wheat Model Vs Conventional Wheat Fertilizer Application Management in Morang, Nepal

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Abstract

Wheat (*Triticum aestivum* L.) production is very sensitive towards the proper nutrient dose and its application methods. Wheat production in Nepal is declining due to inadequate fertility application and/or management program. Nutrient Expert® (NE) Model was adopted to compare with the conventional fertilizer application. Thus, the objectives of this research were to assess the adopted Nutrient Expert® Model vis-à-vis its conventional counterpart in Morang District of Nepal. The experiment was conducted from January 2015 to August 2017 in Itahara and Babiyabirta of Morang district of Eastern Nepal. The experiment comprised of two treatments and twenty replications. The results showed that there is a significant yield difference between the adopted Nutrient Expert® software doses compared to the farmers' conventional practices. The percent increase in the grain yield among the treatments was 95.33% in Nutrient Expert® compared to the conventional system. Significantly, higher net return was recorded in treatment NE (Nepalese Rupee (NRs.) 47,968) than the farmers' fields practice (NRs 10,784). Field experiment validation confirmed that the Nutrient Expert® Wheat model could be used as a practical tool for the decision support system to make a more authentic fertilizer recommendation.

Keywords: fertilizer recommendation, nutrient expert, wheat, productivity, yields, profitability

1. Introduction

According to FAOSTAT (2017), wheat is the third most important cereal crop in Asia, after maize and rice. It is also one of the most important crops in terms of yields. In Nepal, wheat was a minor cereal in the early 1960s and now it is the third most important staple food crop. Wheat is grown on 735, 850 hectares (Ha) with a total production of 1, 879, 191 metric tons (MT), equivalent to 2.55MT/Ha (FAOSTAT, 2017). Currently, yields are decreasing, lower than potential yield, because of poor nutrient management in farmers' field. Nutrient imbalances, inefficient fertilizer use and large losses to the environment are blamed for the decreasing trend, especially over the use of nitrogen fertilizer. Having access to a science-based fertilizer recommendation is critical for the improvement of fertilizer use efficiency in high yielding crops. However, establishing fertilizer recommendations suitable for smallholder farming households in Nepal remains a challenge.

Nutrient Expert® Wheat model, developed by the International Plant Nutrition Institute (IPNI), is a simple computer-based tool, which provides guidelines for nutrient management. The software determines the requirements of crop nutrient uptake by using the principles of site-specific nutrient management (SSNM) which include the use of the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model. The core of the fertilizer recommendation method in Nutrient Expert® for wheat is based on yield response and agronomic efficiency (AE) which is used when soil testing is not available. It also considers the Nitrogen, Phosphorus and Potassium (N-P-K) interactions, which is a unique feature compared with other decision support systems.

The determination of fertilizer N requirements from Nutrient Expert® has been modified to use a target agronomic efficiency and an estimation of yield response to applied N and the determination of fertilizer P and K requirements consider the internal nutrient efficiency combined with estimates of attainable yield, nutrient balances and yield responses from added nutrient within specific fields (Witt *et al.,* 2007).

The Nutrient Expert® Wheat model recommends doses of nutrients based on soil indigenous nutrient supply to avoid excessive nutrient accumulation in the soil. This model has been applied with success in rice, maize and wheat crops in some Asian countries (Witt *et al.,* 2007; Satyanarayana *et al.,* 2013).

Several studies and evaluation trials conducted by Kumar *et al.,* (2012); Pampolino *et. al.,* (2012); Dutta *et al.,* (2014); and Xu *et al.,* (2014); in India and other Asian countries have evidently underlined the superiority of Nutrient Expert® tool's recommendation over farmers' indigenous practice and blanket recommendation from state in terms of both yield and profitability. Nutrient management through Nutrient Expert® also helps address adverse impacts of climate change through mitigation of greenhouse gases emitted from agricultural fields. Thus, NE has now been selected as the best Information and Communication Technology (ICT) solution for improving rural livelihood in Asian.

This model, however, is at the initial stage of testing and validation in our context. Consequently, the objectives of this research are to identify the best ways of managing the wheat nutrition and other best management practices to sustain higher wheat production in the Mid Hills and Terai Regions of Nepal and to evaluate the validity of the software Nutrient Expert® -Wheat model in the Morang district (Fonsah *et al.,* 2018; Kaninda *et al.,* 2015).

2. Materials and Methods

The experiment was conducted in farmers' field by the Forum for Rural Welfare and Agricultural Reform for Development (FORWARD), Nepal in amalgamation with Non-Resident Nepali Association (NRNA), Australia and International Plant Nutrition Institute (IPNI), Delhi project "Transfer, Evaluation and Dissemination of an Innovative Fertilizer Management Tool (Nutrient Expert®) for Increasing Crop Yields and Farmers' Income in Eastern Nepal". The research was conducted from January 2015 to August 2017 by two Village Development Committees (VDCs) of Morang viz. Itahara and Babiyabirta of Eastern Terai.

Twenty wheat-growing farmers, eighteen males and two females, were selected randomly for the trial. The prepared questionnaire was filled out and individual farmers interviewed from which mostly wheat cultivation practices and nutrient management practices were recorded. Collected data was incorporated into NE® Wheat model software. Different nutrient doses with respect to nitrogen from urea, phosphorus from Di-ammonium phosphate (DAP) and potassium from potash were recommended for different farmers for different fields as per the Nutrient Expert tool. Yield and profit simulation of wheat at 13.5% moisture were done by using Nutrient Expert® Wheat model for both the treatments and compared with the actual yield and profit to validate the model's recommendation. Five samples were collected to determine the nutrient content of farmyard manure (FYM) and poultry manure and sent to IPNI research laboratory.

A completely randomized block design comprising two treatments and twenty replications was used. The treatments were Farmers' Fertilizer Practice (FFP) and Nutrient Expert®. Gross plot size was 100 m^2 while the net plot size was 10 m^2. Both NE® plot and FFP plot were manually weeded. Two weedings were done at 30 days interval after seeding (DAS) and 25 days interval after first weeding in NE® plot while single weeding at 30 DAS was done in FFP plot. All the dose of phosphorus and potash was applied at a basal dose and nitrogen was applied at split dose half at basal and half after 25 and 20 DAS.

Growth and yield attributes, such as plant height, effective tillers, spike length, grains per spike, grain yield, etc., as well as economic parameters (cost of cultivation, gross revenue, net revenue and benefit-cost ratio) were observed, recorded and analyzed. IBM® SPSS Statistics® version 16.0 and GenStat® (15^{th} edition) were used for statistical analysis. ANOVA was performed at 0.05% level of significance.

3. Results and Discussions

3.1 Simulated Yield Given by Nutrient Expert® Wheat Model Software at 13.5% Moisture (Ton Per Ha)

The highly significant result was obtained between FFP and NE in terms of simulated yield from Nutrient Expert® Wheat model. The simulated yield of NE (4.13 tons ha-1) field was found greater than FFP (2.05 tons ha-1). The higher yield was due to proper nutrient management that was recommended by the Nutrient Expert® tool, which resulted in high tillering and a greater number of grains per spike (Table 1).

The difference between the two treatments, Nutrient Expert® and Farmers' Field practice, on revenue per/ha was found highly significant. Revenue from NE® (NRs 82,500) was higher and nearly two times more than that of FFP (NRs 41,000). More generation of revenue was due to more yields obtained from appropriate nutrient applications (Table 1).

Table 1. Simulated Yield and Economics Analysis of Nutrient Expert® Wheat Model Software at 13.5% moisture, in Morang District in 2015

Treatment	Yield at 13.5% moisture (MT/ha)	Revenue (NRs/ ha)	Cost of seed and fertilizers (NRs/ ha)	Expected benefit above seed and fertilizers (NRs/ ha)	% Increased
Nutrient Expert®	4.13	82,500	15,709	66,791	44.08
Farmers' field practice (FFP)	2.05	41,000	11,552	29,448	
SEm (±)	0.0215	4,291	205.4	448.5	
LSD (P = 0.05)	0.0668 **	1,335.5 **	639.4 **	1,395.9 **	

** = Highly Significant * = Significant and NS = Non-significant

The result was highly significant on the cost of seed and fertilizer between the two treatments. Seed and fertilizer costs were higher in NE® as compared to FFP. Higher cost in NE was obtained because nutrient used in the treatment Nutrient Expert® was higher than nutrient practices by farmers' (Table 1). Also, more care and management in Nutrient Expert® recommended practice results into high cost over FFP.

The highly significant difference was observed on the expected benefit about seed and fertilizer cost between the treatments. NE provided the benefit of NRs 66,791 as compared to the NRs 29,448 by FFP. The percentage increased in expected benefit in NE above FFP is approx. 44% (Table 1).

3.2 Evaluation of Nutrient Expert® Wheat Model

3.2.1 Comparison of Nutrient Expert® Estimated Attainable Wheat Yield Versus Actual Wheat Yield and Estimated Revenue Versus Actual Gross Revenue

A paired-samples t-test was conducted to compare estimated attainable wheat yield given by Nutrient Expert® tool with the observed wheat yield for both the treatments. There was no significant difference in estimated attainable yield (M=4.12, SD=0.43) and actual yield (M=4.08, SD=0.32); t (11) = -0.758, p = 0.464 in treatment Nutrient Expert®. Similarly, no significant difference was observed between estimated actual yield (M=2.05, SD = 0.391) and observed yield (M=2.016, SD = 0.183); t (11) = -0.392, p = 0.703 in treatment Farmers' Field practice. These results confirmed the validity of the simulated yield provided by the Nutrient Expert® Wheat model for both the treatments in farmers' field (Table 2).

Table 2. T-test for comparing estimated attainable yield and actual yield of wheat in Morang District, 2015.

			Paired differences			
	Mean	Standard deviation	Mean	Standard deviation	T-test	P-value
Estimated yield for NE®	4.125	0.43	-0.0411	0.188	-0.758	0.464
Actual yield of NE®	4.018	0.32				
Estimated yield for FFP	2.05	0.39	-0.033	0.293	-0.392	0.703
Actual yield for FFP	2.057	0.18				

Estimated revenue obtained from Nutrient Expert® was compared with actual gross revenue in both the treatments by using a paired samples t-test in which no significant difference was obtained between estimated revenue (M = 82500, SD = 8660.3), and actual gross revenue (M = 81676.7, SD = 6433.9); t (11) = -0.758, p = 0.464 in treatment Nutrient Expert®. In treatment Farmers' Field practice also, no significant difference was observed between estimated revenue (M = 41000, SD = 7839) and gross revenue (M = 40336.7, SD = 3679.8); t (11) = -0.392, p = 0.703 (Table 3).

Table 3. T-test for comparing estimated revenue and actual gross revenue of wheat in Morang district in 2015

	Paired Differences					
	Mean	Standard deviation	Mean	Standard deviation	T-test	P-value
Estimated yield for NE®	82500	8660.3	-823.3	3762.9	-0.758	0.464
Actual yield of NE®	81676.7	6433.9				
Estimated yield for FFP	41000	7839.3	-663.3	5865.7	-0.392	0.703
Estimated yield for FFP	40336.7	3679.8				

3.3 Plant Height

Plant height of wheat variety NL 297 was significantly affected by the treatments of nutrient management practice. The height of the plant was found more in treatment NE® (0.99m) than in treatment FFP (0.93m). This result is similar to the findings of Haq et al., (2002) which reported that the highest plant height was found in high and balanced NPK fertilizer (Table 4).

Table 4. Analysis of different yield attributes of wheat in Morang district of Nepal in 2015

Treatment	Plant height (m)	Effective tillers (m^2)	Spike length (cm)	Grains/spike
NE®	0.99	363	7.912	53
FP	0.93	271	6.70	45
SEm	0.0119	7.48	0.10	0.72
LSD (P = 0.05)	0.035**	22.14**	0.32**	2.14**
CV %	5.6	10.5	6.6	6.6

Highly Significant = **, Significant = * and Non-significant = NS

3.4 Effective Tillers

A significantly higher number of effective tillers per square meter was noticed in the treatment of NE® (363) over the treatment FFP (271). Balanced and optimum use of fertilizer application increases the number of effective tillers (Uddin *et al.*, 1998; Haq *et al.*, 2002) (Table 4).

3.5 Spike Length

Significantly longer spike length was obtained in the treatment NE® (7.91cm). Significantly shorter spike length was obtained in FFP (6.71 cm). This may probably be the result of improved nitrogen status of the plant during its entire growth period (Table 4).

3.6 Grains per Spike

A number of filled grains per spike differ significantly with different nutrient management practices. The filled grains per spike were higher in NE® (53.27) while lower in FFP (45) (Table 5).

Table 5. Effect of nutrient management on grain and straw yield of wheat on Morang District of Nepal in 2015

Treatment	Grain yield (tons per ha)	Yield difference over FFP	Increased %	Straw yield (tons per ha)	Yield difference over FFP	Increased %
NE®	4.018	+1.961	95.33	3.547	+0.508	16.71
FFP	2.057			3.039		

3.7 Wheat Grain Yield

The difference among the treatments on grain yield was significant. The yield of wheat grain was found to be 4.018 tons per ha in NE® nutrient management practice while it was found to be 2.057 tons per ha. The yield in treatment NE® is nearly 2 tons per ha more than that of treatment FFP and increased grain yield percentage of wheat in NE® over FFP is 95.33% (Table 5) (Fonsah *et al.*, 2007).

The results of the experiment conducted in China showed that the mean yield responses of wheat to N, P and K were 1.7, 1.0 and 0.8 tons per ha, respectively. Nitrogen was the nutrient most limiting yield, followed by P and then K. The soil indigenous nutrient supplies were 122.6 kg N/ha, 38.0 kg P/ha, and 120.2 kg K/ha. The mean agronomic efficiencies were 9.4, 10.2 and 6.5 kg/ha for N, P and K, respectively (Chuan *et al.*, 2013).

Biradar *et al.* (2006) also reported that overall increase in the yield under SSNM was in the range of 8 to 24 percent over blanket recommended dose and 20 to 37 percent over in rice, wheat and chickpea. Other studies using the NE® model for maize and rice showed significant yield advantages from the tool-based fertilizer recommendation as compared to existing practices (Satyanarayan *et al.*, 2013; Sapkota *et al.*, 2014). Dobermann et al., (2002) also reported the same result that NE® or SSNM practice showed an increased yield more than that of the farmer practice in rice crop.

3.8 Straw Yield

Straw yield differs significantly with different nutrient management practices. In the treatment NE®, the straw yield was obtained as 3.55 tons per ha, which is higher than yield in FFP (3.04 tons per ha). The straw yield in treatment NE® is nearly 0.5 tons per ha more than that of treatment FFP (Table 5). The increased straw yield percentage of wheat in NE® over FFP is 16.71% (Table 5).

Straw yield is the function of vegetative growth. Balanced and optimum use of fertilizer increased plant height, green leaves per hill, tillers per hill and dry matter production which finally resulted in higher straw yield.

3.9 Biological Yield

The difference in biomass yield among the treatments NE and FFP were found to be significant. The biomass yield in NE was obtained as 7.565 tons per ha which is much higher than that of FFP i.e. 5.1 tons per ha (Table 6). The higher yield of biomass in NE was due to the higher straw and grain yield over FFP (Fonsah *et al.*, 2010).

Table 6. Wheat yields of two nutrient management practices on Morang district of Nepal in 2015

Treatments	Grain yield	Straw yield	Biological yield	Harvest index (HI)
NE®	4.018	3.547	7.565	53.27
FFP	2.057	3.039	5.1	40.31
Sem	0.057	0.1	0.12	0.83
LSD (P = 0.05)	0.17**	0.28**	0.34**	2.45**
CV %	8.4	12.9	8.2	7.9

Highly significant = **, Significant = * and Non-significant = NS
Note: Biological yield, grain yield and straw yield are in tons per ha

3.10 Harvest Index (Hi)

The treatment of nutrient management showed a significant result. In treatment NE®, HI was 53.27% while in FFP was 40.31% (Table 6). More economic yield in NE® plot over FFP accounted for high harvest index in NE® plot.

3.11 Economic Analysis

3.11.1 Cost of Cultivation (CC)

Difference between the costs of cultivation among the treatments was highly significant. The cost of cultivation was higher in NE® (NRs 33,709) than in FFP (NRs 29,552) (Table 7). Higher cost in treatment NE® is due to the application of a large proportion of a nutrient that is much more than nutrient proportions in FFP (Table 7).

3.11.2 Gross Revenue (GR)

The highly significant result was observed between the treatments on gross return from the wheat production. Higher gross return, NRs 80,364, was in treatment Nutrient Expert® and lower, NRs 41,132, was in treatment Farmers Field practice. The reason for the high gross return in NE® is due to an increase in grain yields than in FFP system (Table 7).

Table 7. Economic analysis of wheat production on Morang district of Nepal, 2015

Treatment	CC	GR	NR	B: C ratio
NE®	33709	80364	47968	2.421
FFP	29552	41132	10784	1.367
LSD	639.4**	3372**	2465.3**	0.0713**
Sem (±)	205.4	1139.2	792	0.0229
CV%	2.9	8.4	12.1	5.4

** = Highly Significant, * = Significant and NS = Non-significant
Note: Cost of cultivation, gross return and net return are in Nepalese rupees.

3.11.3 Net Revenue (NR)

The difference between net revenue among the treatments was highly significant. Table 7 depicts that net revenue in FFP was NRs 10,784, which was less than net revenue in NE® (NRs 47,968). Kumar *et al.*, (2012) also reported from the experiment conducted in Haryana that, farmers can expand their profit through Nutrient Expert® tool over their own traditional fertilizer management practice.

3.11.4 Benefit-Cost Ratio

Benefit-cost ratio differs significantly between the two treatments. The higher benefit-cost ratio was obtained in NE® (2.42) over FFP (1.37). It is because of the higher gross return above the cost of cultivation in treatment NE over FFP (Table 7) (Fonsah *et al.*, 2007; Fonsah *et al.*, 2008).

4. Conclusion

The research showed the difference between the treatments was highly significant regarding plant height (m), effective tillers per square meter, spike length (cm), grains per spike, grain yield (MT/ha), straw yield (MT/ha) and harvest index (%). However, maximum values for all these parameters were concentrated in NE® plot. Maximum yield was obtained from NE® plot, which was followed by FPP. In addition, the cost of cultivation (NRs/ha), gross return (NRs/ha), net return (NRs/ha) and benefit-cost ratio differed significantly among the treatments. The high net return was generated from NE plot (NRs 47, 968) over FFP plot (NRs 10, 784).

Comparison of Nutrient Expert® estimated attainable wheat yield given by Nutrient Expert® Wheat model versus actual wheat yield in farmer fields validate Nutrient Expert® Wheat model.

Thus, higher yield and maximum profit can be obtained from Nutrient Expert® Wheat model. Although the model is easy to use, farmers could find technical difficulties and feel unsecured to use it. In order to increase the national wheat production and national revenue through the Nutrient Expert® Wheat model, it is fundamental to educate agricultural extension agents about the use and benefits of the model as they have an important role in encouraging farmers to accept and adopt the new technology.

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