



## Research article

## Assessment of Nutrient Expert ®-Hybrid maize model on productivity and profitability of winter maize in Terai region of eastern Nepal

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## ABSTRACT

Inadequate, unscientific, and lack of optimum utilization of fertilizer management devoid of site-specific nutrient management have been the significant constraints of maize (*Zea mays* L.) production in Nepal. Therefore, a multi-locational farmers' field was planned and executed at two VDCs of Morang district in the Terai region of Nepal from December 2015 to May 2016. Nutrient Expert (NE) and Farmer's Fertilizer Practices (FFP) treatments were imposed in a randomized complete block design (RCBD) with twenty replications. The research explored highly significant results in terms of plant number m<sup>-2</sup>, cob numbers m<sup>-2</sup>, cob length, kernel rows cob<sup>-1</sup>, kernels kernel row<sup>-1</sup>, test weight, grain, stover, and biological yields and harvest index. NE showed the highest yield (8.06 tons ha<sup>-1</sup>) among the two treatments tested than FFP (4.52 tons ha<sup>-1</sup>). While comparing net revenue, NE-based fertilizer recommendation gave the significantly higher (NRs.151.116 thousand ha<sup>-1</sup> equivalent to \$1281 ha<sup>-1</sup>) result than FFP (NRs.84.834 thousand ha<sup>-1</sup> equivalents to \$707). The result suggests adopting NE practices to minimize the yield gaps and increase the productivity of maize in Morang and adjoining agro-climatic conditions of eastern Terai, Nepal.

## 1. Introduction

Maize (*Zea mays* L.) is the most important cereal crop in Nepal, grown under diverse environmental conditions (MOAD, 2014). It is a principal food product in the hilly region and animal feed industries in the Terai region of Nepal (DeJonge et al., 2015). Ranum et al. (2014) reported per capita maize consumption in Nepal is the highest in South Asia. The farm-level yield of maize (2.45 t ha<sup>-1</sup>) is not satisfactory as compared to the attainable yield (5.7 t ha<sup>-1</sup>) in Nepal (MOAD, 2014; DeJonge et al., 2015). Several new methods, such as proper cultivars and timely inter-cultural operations, have raised maize production in Nepal (Amgain et al., 2021). Much improved technology has been developed in Nepal. If these could be given to the farmers shortly, the export potential could be raised, and the income of farmers, as well as the economic status of the country, may be raised (Dahal et al., 2018). It has been observed that the increasing trends of consuming more quantity of protein and micronutrient-rich food items in Nepal in recent days compared to last decades (MOAD, 2016; MOAD 2020).

Nutrient Expert ® (NE)- Hybrid maize is an interactive, computer-based decision support system (DSS) that supports researchers, extension workers, and farmers to recommend site-specific fertilizer

applications and determine the field's nutrient balance. It analyzes profit and costs by comparing the price and outcomes of previous crops and from the blanket recommendation. It was developed from on-farm research data and validated over five years of testing in India and other developed countries globally (Timsina et al., 2021). From many experiences, this tool was first developed in 2009 by the joint effort of IPNI (International Plant Nutrient Institution), CIMMYT (International Maize and Wheat Improvement Centre), and the National Agriculture Research System for maize and wheat in India. It has been obtaining popularity among South Asian countries, including Nepal. NE follows the principles of site-specific nutrient management (SSNM). SSNM is a plant-based approach and was first developed for rice (Dobermann et al., 1997; Witt et al., 2009) and later developed for other cereals maize and wheat too (Timsina et al., 2014; Majumdar et al., 2014; Zhang et al., 2017; Dahal et al., 2018; Wang et al., 2020; Huang et al., 2021). It provides guidelines to farmers about when and how much fertilizers are to be applied in that specific season and location (Timsina et al., 2014).

There is a considerable yield gap in maize because of more significant variability in the climate in Nepal, having the potentiality to produce a variety of food crops. In Nepal, only 71 % of the land is cultivated out of total cultivable land, and cereal crops contribute 49.41% of the national

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**Table 1.** Initial soil fertility status of trial sites in Terai region of Nepal tested by IPNI.

Regions	Samples	SOC (%)	Soil pH	Available nutrient contents		Micronutrients
				Phosphorus (kg/ha)	Potassium (kg/ha)	Zn (ppm)
Itahara, Morang	Experimental site	0.69	6.2	34.6	169.2	0.80
	FYM		9.1	0.22	0.93	
Babiyabirta, Morang	Experimental Site	0.80	6.4	14.1	38.5	
	FYM		8.4	0.42	1.5	

GDP (MOAC, 2009). Maize, followed by rice, is considered one of the important cereal crops in Nepal. However, population growth, increased demand for food, and lack of commercial farming have turned Nepal gradually from a food-exporting country to a food-importing country within a few decades (Sapkota and Pokhrel, 2010). Disease and pest infestation, weed, declining soil fertility, low seed replacement rate, etc., have been the significant constraints of agriculture in Nepal. In this context, existing fertilizer recommendations followed by government bodies and research stations are mainly focused only on N, P, and K for vast areas without considering the site-specific soil and weather conditions. This negligence has resulted in under-fertilization in major regions and over-fertilization in Terai pockets (Amgain et al., 2021; Kunwar et al., 2019). In most cases, there is lower use of all nutrients, while in some cases relatively higher use of nitrogen (N) and phosphorus (P) and lower use of potassium (K), secondary (S, Ca, and Mg), and micronutrients (Zn, Fe and B).

The nutrient requirement varies from field-to-field due to high variability in soil fertility across farmer fields, and single homogenous and sub-optimal official government recommendations may not be very useful in improving maize yields (Gautam et al., 2019). Thus, this research was conducted to understand the SSNM with objectives of a) upgrading the economic status of farmers by increasing the productivity of maize, b) assessing the profitability of farmers by using blanket recommendations, and c) validate the NE maize model in Morang district, Nepal.

## 2. Materials and methods

The multi-locational on-farm experiment was conducted in two Village Development Committees (VDCs) of Morang district, namely Itahara (26.55° N, 87.63° E) and Rajghat (26.63° N, 87.63° E), in eastern Nepal from December 2015 to May 2016.

Hybrid maize cultivar Pioneer- 3785 was planted following Randomized Complete Block Design (RCBD) with two treatments NE (Nutrient Expert® - Hybrid Maize model with recommended fertilizer dose) and FFP (farmer use their practice of seed rate and fertilizer dose). Line method of sowing was performed, and sowing depth was maintained 6 cm–7 cm in both the NE and FFP plots. The gross plot size is 100 m<sup>2</sup> and the net plot size is 10 m<sup>2</sup>. Spacing for NE was 60 × 20 cm<sup>2</sup>, and for FFP, it varied from 70 × 30 cm<sup>2</sup>, 75 × 35 cm<sup>2</sup> to 70 × 25 cm<sup>2</sup>. For both NE and FFP, irrigation was applied 40 days after seeding (DAS), 60 DAS, and 80 DAS.

Twenty maize growing farmers, ten from each VDC, were selected randomly and were interviewed on their package of the practice of Maize cultivation. Also, the questionnaire on the Nutrient Expert®-Maize model was filled based on the interview with the farmers. The data based on the questionnaire was loaded into the software, and different doses of Nitrogen, Potassium, and Phosphorous were recommended through urea, muriate of potash, and di-ammonium phosphate. Soil samples from the experimental sites and farmyard manure were tested at the lab of IPNI, India. The results from IPNI are presented in Table 1.

Based on the soil fertility status, the Nutrient Expert®- Maize model provided the nutrient recommendations and simulated yield. Farmers were also using Farmyard Manure in their fields, which was considered during the NE recommendation. Thus, the application of fertilizers on

**Table 2.** The average application rate of fertilizers (kg ha<sup>-1</sup>) under NE & FFP (n = 20).

	Nitrogen (N)	Phosphorus (P <sub>2</sub> O <sub>5</sub> )	Potassium (K <sub>2</sub> O)
Itahara			
NE	75	243	110
FFP	48	162	15
Rajghat			
NE	85	220	305
FFP	48	117	17

Note:

NE: Nutrient Expert plots and FFP: Farmers Fertilizer Practices.

Nutrient Expert (NE) plots was based on the recommendation from the Nutrient Expert model, while on Farmers Fertilizer Practices (FFP) plots were based on the farmer's practice of fertilizer management. Table 2 shows the average nutrients dose applied to the FFP plots and NE plots.

Pre-harvest observations like cob numbers, cob lengths, and plant numbers were measured from 10 m<sup>2</sup> plots. However, the results have been expressed and analyzed in a square meter. Similarly, post-harvest observations like kernel rows per cob, seed numbers per cob, test weight, grain yield, and stover yield were measured. Pre-harvest observations were used to compare yield attributes of maize in two different treatments. Similarly, post-harvest observations were used to calculate the biological outcome, stover ratio, and harvest index for yield response analysis in two treatments. After the crop's maturation, all the plants from the net plots were harvested to record the grain yield. The weight of the harvested cob was taken. Grain yield was adjusted at 15.5% moisture, and this moisture percentage was calculated using the digital moisture meter. Weight after drying and reducing moisture of stover was recorded. We added grain yield and stover yield to get the total biological yield.

For economic analysis, we performed a simple cost-benefit analysis. For the cost of cultivation, prices for inputs on surrounding agro vets were made the primary basis. The average price of maize in the local market was used to calculate gross revenue. Finally, the benefit-cost ratio was calculated as a ratio of gross return to the cost of cultivation.

Statistical analysis was performed using IBM® SPSS Statistics® version 16 and GenStat®, 15<sup>th</sup> edition. For mean separations, all the recorded data were subjected to analysis of variance and Tukey's test at a 0.05% level of significance (Gomez and Gomez, 1984; Duncan 1955).

## 3. Results and discussions

### 3.1. Yield attributes

The different nutrient management practices experiment showed significant results concerning all the yield attributes (Table 3). The average number of plants per square meter was nearly double in NE than that of FFP. This result can be explained by dense planting in the NE treatment recommended by the Nutrient Expert – Maize model.

Similarly, cob numbers per square meter were also found to be greater in NE. Cob number in a plant is generally a genetic character in which nutrition may not be crucial. However, the number of ears per plant

**Table 3.** Yield attributes of maize as affected by nutrient management practices at Morang district.

Treatment	Plant number (m <sup>-2</sup> )	Cob number (m <sup>-2</sup> )	Cob length (m <sup>-2</sup> )	Number of kernel rows per cob	Seed number per cob	Test weight
NE	7	8	18.87	14	595	327.5
FFP	4	5	15.71	13	456	292.5
LSD	0.43	0.45	0.65	0.36	30.56	0.013
CV %	11	11	5.7	3.9	8.8	6.3
Significance	**	**	**	**	**	**

Note:

\*\* : Highly significant, \* : Significant and NS: Non-significant.

Test weight is expressed in a gram of 1000 grains.

increases with fertilizers (Bangarwa et al., 1988). Thus, an increase in several ears per plant might be responsible for increasing cob numbers per square meter in NE treatment compared to FFP.

The average cob length was found longer in NE treatment over FFP. Also, the NE treatment performed better in terms of kernel rows per cob compared to the FFP treatment. The higher nitrogen level is associated with an increase in the number of kernel rows in a cob (Gungula et al., 2007).

We observed more than 100 seeds per cob on average in NE (595) compared to FFP (456). Albeit more seeds in the NE treatment partly can be explained by longer cob length and a more significant number of kernel rows per cob, it is more defined by the plant's response to nutrients during the grain filling stage. We observed more immature seeds and incomplete grain fillings in FFP plots compared to NE plots. Nitrogen with other nutrients is responsible for longer seed filling duration and physiological maturity (Rai, 1961).

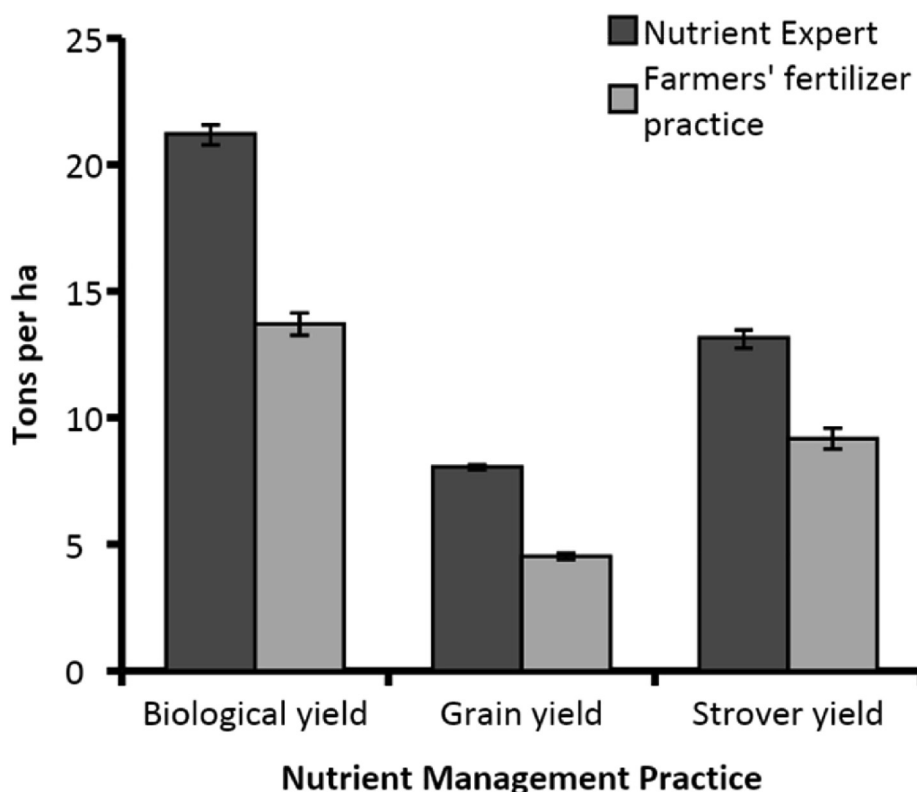
### 3.2. Yields

The difference in grain yields was found to be highly significant between the two treatments. The average grain yields for the NE and FFP plots were 8.06 tons per ha and 4.52 tons per ha, respectively (Figure 1).

NE recommendation ensured all required nutrients and micronutrients causing the increase in yield than in farmers' own traditional nutrient management practices (Pampolino et al., 2012).

The relative performance of NE hybrid maize was found to be better than the FFP. The primary role of adequate nutrients in the plant's metabolism is responsible for a higher yield in the NE treatment. As discussed earlier, proper nutrient recommendations from NE software significantly resulted in better yield attributes such as cob length, number of kernel rows per cob, seed number, etc., which ultimately led to the higher production per unit area in the NE treatment. Similar results are supported by several previous studies that suggested a significant increase in grain yield applying tool-based fertilizer recommendations compared to existing practices (Sapkota and Pokhrel, 2010; Amgain et al., 2021). We found a 78.31% increase in an attainable yield using NE software for nutrient recommendations over farmers' traditional practices. This result is in line with Xu et al. (2016), which showed that the attainable yield of maize could be increased by 80 % by using NE as a result of nitrogen use efficiency.

Likewise, different nutrient management practices had a significant effect on stover yield as well as biological yield. The average stover yield in NE is 43.35% more than FFP, while the average biological yield is 54%



**Figure 1.** Comparison of different yield and harvest index in two treatments.

**Table 4.** Yield gap analysis between two treatments.

Treatment	Grain yield	Grain yield gap	Stover yield	Stover yield gap	Biological yield	Biological yield gap	Harvest index (%)
NE	8.06	78.31%	13.16	43.35%	21.22	54%	38.11
FFP	4.52		9.18		13.70		33.43

Note:

Yields are expressed in tons per hectare.

**Table 5.** Analysis of average cost involved in the experiment.

Treatment	Cost of cultivation	Gross revenue	Net revenue	Increased in NRs on NE over FFP	Benefit-cost ratio
NE	47598	151116	103552	+143.20 %	3.18
FFP	42748	84834	42578		1.995
LSD	956.3	5587.8	5566.3		0.13
CV	3.2	7.2	11.5		12.8
Significance	**	**	**		**

Note:

Costs and revenue are expressed in NRs per hectare.

(1 USD – NRs 115).

\*\* : Highly significant, \* : Significant and NS: Non-significant.

more. Nitrogen plays a prime role in accelerating photosynthesis rate resulting in more carbohydrate production and enhancing vegetative growth (Sanjeev et al., 1997; Majumdar et al., 2014; Shrestha, 2015) (see Table 4).

### 3.3. Cost-benefit analysis

The total cost of cultivation of maize in a hectare was found to be NRs. 47, 598 in NE treatments and NRs. 42,748 in FFP treatments on average. The difference in the cost was significant between the treatments. The higher cost of cultivation in NE treatments is due to the application of a higher amount of nutrients and labor cost than the FFP. Likewise, the gross revenue from NE was higher than that of FFP (Table 5).

Sapkota et al. (2021) has reported that even though the cost of fertilizers is more in NE, the greater grain yield can compensate for the cost over FFP. This study has been aligned with our results. The greater gross revenue at NE was due to higher production from optimum fertilizer recommendation from SSNM using NE software. Pasuquin et al. (2010) found 85 % higher gross revenue due to NE over FFP in maize. Net revenue in NE was 143.20 % greater than FFP. Thapa et al. (2020) also reported that the net revenue and crop production could be increased with NE recommendation by 12%. Site-specific nutrient management has been providing an adequate amount of nutrients to the plants resulting from the maximum attainable yield among different cereal crops, which has ultimately increased the benefit of production. Similar findings were reported in the previous experiments with rice and wheat production in various districts of Nepal (Amgain et al., 2021; Kunwar et al., 2019; Mannade et al., 2017).

## 4. Conclusions

The present study highlights the significantly higher values of yield, yield attributes, and revenues in the NE treatment compared to the FFP. The yield gap between the NE and FFP treatments was nearly 80%. In summary, the greater yield and profit maximization were obtained from the Nutrient Expert Hybrid Maize model. Hence, greater yield and higher revenues inferred that farmers of eastern Terai could advocate the site-specific nutrient management practices in Nepal for higher productivity and profitability. The limitation may include technical difficulties, the use of these models at the complex agroclimatic region, and the

affordability of farmers to meet the required nutrients demand. However, the proper extension of education regarding the model and further experiments on diverse agro-climate can enhance site-specific nutrient management practices.

## Declarations

### Author contribution statement

Sujata Bogati: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Saurav Raj Kunwar: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Lal Prasad Amgain: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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### Data availability statement

Data will be made available on request.

### Declaration of interests statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

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