Assessment of productivity and profitability of wheat using Nutrient Expert®-Wheat model in Jhapa district of Nepal

Ram Datta Bhatta a,*, Lal Prasad Amgain a, Roshan Subedi a, Bishnu Prasad Kandel b

a Tribhuvan University, Institute of Animal and Plant Science, Lamjung Campus, Lamjung, Nepal
b Department of Plant Breeding, Post Graduate Program, Institute of Agriculture and Animal Science, Tribhuvan University, Kirtipur, Nepal

ABSTRACT

Wheat is the third most important cereal crop in Nepal after rice and maize both in area and production, but its productivity of 2.3 tonne ha\(^{-1}\) is very less compared to other developed countries (6 tonne ha\(^{-1}\) for Switzerland and China) in the world. The main cause of low wheat yield in Nepal is the improper and inadequate use of fertilizer. Therefore, a farmer's field experiment was conducted during November 2015 to April 2016 to rectify the best fertilizer management options at two sites of Damak and Gauradaha in Jhapa district in eastern-Terai of Nepal using Nutrient Expert®-Wheat model. The research was accomplished in Randomized Complete Block Design with 2 treatments and 20 replications, considering farmers' field as replication. Two treatments included in the experimentation were NE® (Nutrient Expert Recommendation) and FFP (Farmer's Fertilizer Practices). The statistical result revealed the highly significant difference in terms of number of effective tiller m\(^{-2}\), plant height, filled grain per spike, spike length, grain, straw and biological yields and harvest index. The highest yield (4.71 tonne ha\(^{-1}\)) was obtained from NE® field as NE® based practices produced 58 % higher yield in comparison to FFP. NE® based treatment produced significantly higher biomass yield, yield attributes and cost-benefit ratio than FFP treatments. Field experiment validation confirmed that the Nutrient Expert® Wheat model could be used as the most adoptable and practical precision decision support system tool to make a more authentic fertilizer recommendation in eastern-Terai of Nepal.

Keywords: Agriculture, Farmers practice, Nutrient Expert®-Wheat

ARTICLE INFO

1. Introduction

Wheat (Triticum aestivum L.) belongs to family Gramineae and the tribe Hordeae. It is the most important winter crop and third important cereal crop after rice and maize in Nepal. Wheat is grown all three domains (agro-climatic regions) of the country, ranging from sea level to 4000 m. Wheat is grown in 745,823 ha with total production of 1,736,849 metric tonne and the productivity of 2.33 tonne ha\(^{-1}\). Wheat is grown in 745,823 ha with total production of 1,736,849 metric tonne and the productivity of 2.33 tonne ha\(^{-1}\) in Nepal [1]. Wheat shares about 7.14 % in national Agriculture Gross Domestic Product (AGDP) [2]. The productivity of wheat in Nepal is very low i.e. 2.50 tonne ha\(^{-1}\) [1], whereas, other developed countries such as Switzerland and China produced 6 tonnes ha\(^{-1}\) [3]. The highest productivity of wheat was recorded in New Zealand i.e. 16.79 tonne ha\(^{-1}\) [4]. This lower productivity on high yielding and improved varieties of wheat is cadre for the lack of scientific knowledge on the use of fertilizers, insecticides, pesticides and management practices wherein, improper fertilizer management tops the agenda. Hence, the concept of site-specific nutrient management (SSNM) was introduced with the aim of supplying fertilizers based on specific sites and field conditions with particular growing environment.

SSNM is a component of precision agriculture, which combines the plant nutrient requirements at each growth stage and ability of soil to supply the deficit nutrients. Moreover, Nutrient Expert is a computer-based support tool that helps to estimate fertilizer guidelines based on SSNM principles of 4’ R’ [5]. The 4’ R’ denotes the right dose, right method of application, right source and right time of application. This model has been applied with success in major cereal crops such as maize, rice and wheat in some Asian countries [6, 7, 8] have evidently underlined the superiority of Nutrient Expert® model recommendation over farmers practice and blanket recommendation from state in terms of both yield and profitability. NE® based fertilizer recommendations improve wheat yield by 42 % [9]. The fertilizer requirement for a field is estimated from the expected yield response to each fertilizer nutrient, which is the difference between the attainable yield and the nutrient-limited...
yield. These parameters are determined from nutrient omission trials in farmers’ fields, while attainable yield is the yield for typical year at a location using best management practices without nutrient limitation [8]. This model, however, is at the initial stage of testing and validation in our context.

Eastern-Terai in Nepal is ‘bread-basket’ of food crops, but the farmers on recent days is disappointed to grow wheat due to fewer profit margins from wheat [1, 2]. Therefore, the present experiment was conducted to compare wheat yield and their economic performance of field specific fertilizer recommendation by the precision fertilizer management tool, Nutrient Expert®-Wheat with the existing farmer’s fertilizer management practice, and to develop and evaluate a new SSNM approach and the best crop management practices for wheat through on-farm research in eastern-Terai of Nepal in Jhapa district.

2. Materials and methods

The field experiment was conducted at the farmers’ field in Damak and Gauradaha (26°22’00”N, 88°12’00” E, 70 to 506 masl) of Jhapa District in Nepal. The experiment was conducted in winter season from November 2015 to April 2016. The average values of various soil chemical properties as a routine soil analysis of the experimental soils of two sites (Gauradaha and Damak) have been shown in Table 1. The farmers of both villages commonly practiced Farm Yard Manure (FYM) in their plots under farmers’ fertilizer practices which were taken in consideration while estimating the NE recommendations. The initial soil chemical properties mentioned that the experimental soil at both sites were low in soil organic C, available nitrogen and available potassium but medium in soil available phosphorous. Soil available nitrogen, phosphorous, potash and zinc were measured by Kjeldahl Distilation, Spectrophotometer, Flame Photometer and Atomic Absorption Spectro-photometry method as described by Prasad et al [10]. Soil organic matter was measured by method suggested by Walkley and Black's [11] titration method.

The specific fertilizer doses particularly under FFP and NE-Wheat recommendation for 10 farmers each at Gauradaha and Dhukurpani Damak was fixed after interview using questionnaires embedded on NE Expert®-Wheat model. The recorded and predicted data were entered into NE-Wheat Model Software and different nutrient doses in respect to nitrogen through Urea, phosphorus from Di-ammonium Phosphate (DAP) and potassium from Muriate of Potash (MOP) was recommended for different farmers. Two fertilizers regimes were shown in Table 2. The different recommendation of nutrients (NPK) assigned for individual farmer’s field under FFP and NE-Wheat model varied as per farmer’s practices and only average values have been exhibited in the experiment. The experimental field was laid out in Randomized Complete Block Design (RCBD) with 2 treatments (Nutrient Expert®-Wheat = NE, and Farmer’s Fertilizer Practices = FFP) having 20 replications (no. of farmers = no. of replications) in wheat cultivar NL-297. The plot size was maintained 100 m² with crop management practices for wheat through on-farm research in eastern-Terai of Nepal in Jhapa district.

The average values of various soil chemical properties at a location using best management practices without nutrient limitation [8]. This model, however, is at the initial stage of testing and validation in our context.

Eastern-Terai in Nepal is ‘bread-basket’ of food crops, but the farmers on recent days is disappointed to grow wheat due to fewer profit margins from wheat [1, 2]. Therefore, the present experiment was conducted to compare wheat yield and their economic performance of field specific fertilizer recommendation by the precision fertilizer management tool, Nutrient Expert®-Wheat with the existing farmer’s fertilizer management practice, and to develop and evaluate a new SSNM approach and the best crop management practices for wheat through on-farm research in eastern-Terai of Nepal in Jhapa district.

### Table 1. Average values of soil chemical properties of experimental soils and FYM at Damak and Gauradaha in Jhapa.

| Site | Samples          | SOC (%) | Soil pH | Nitrogen (%) | Phosphorous (kg ha⁻¹) | Potassium (kg ha⁻¹) | Micronutrient Zn (ppm) |
|------|-----------------|---------|---------|--------------|----------------------|---------------------|-----------------------|
| Damak, Jhapa (Avg. of 10 farmers) | Experimental Soil | 0.48 | 5.55 | 0.07 | 34.28 | 71.40 | 0.28 |
| FYM used | | 8.13 | 0.6 | 0.77 | 45.13 | 109.00 | 1.01 |
| Gauradaha, Jhapa (Avg. of 10 farmers) | Experimental Soil | 0.47 | 5.30 | 0.08 | 45.13 | 109.00 | 1.01 |
| FYM | | 7.84 | 0.5 | 1.13 | 1.01 | 0.28 |

Ppm = Parts per million, SOC = Soil Organic Carbon, FYM = Farm Yard Manure.

### Table 2. Application rate of major nutrients applied at NE-Wheat model and FFP.

|          | Application rate kg ha⁻¹ |
|----------|--------------------------|
| Wheat    | N | P | K |
| NE       | 90 | 60 | 35 |
| FFP      | 80 | 40 | 10 |

N=Nitrogen, P=Phosphorous, K=Potash, NE = Nutrient Expert, FFP = Farmer’s Field Practice.

Data on plant height, effective tiller m⁻², spike length, filled grains per spike, were recorded from five randomly selected plants. Grain, straw and biological yields and harvest index were recorded from 25 m² in each farmer’s field for both FFP and NE-Wheat treatments. Harvest index was calculated by dividing grain yield with biological yield and expressed in percentage. Economic analyses of data were calculated by using the formula:

Cost of cultivation was calculated and expressed in NRs ha⁻¹ based on cost of different agriculture inputs viz. labor, fertilizer, compost, and other necessary materials. Gross returns (NRs ha⁻¹) was calculated from economic yield (grain + straw) of wheat on the basis of local market price available in Jhapa districts of Nepal for the year 2015/16. Net returns (NRs ha⁻¹) was calculated by subtracting the cost of cultivation from the gross returns. Benefit-Cost ratio was calculated by dividing gross returns with cost of cultivation. Data were entered in to Microsoft Excel-2010 and analysis and mean variation was performed by using Statistical Package R version 3.6.0 and treatment mean were compared by Least Significant Difference (LSD) at 0.05% level of significance.

### 3. Results and discussion

Plant height at harvest, effective tillers, spike length and filled grains per spike of NL-297 cultivar of wheat was significantly affected by nutrient management treatments (Table 3). Higher plant height was found in NE treatment (115.5 cm) over FFP (94.7 cm). Plant height increased with balanced fertilizer under NE-Wheat. Malghani et al. [12] mentioned that balanced NPK fertilizer produced the highest plant height, whereas minimum height of plant was in no fertilized plot which is in accordance to our finding. Similarly, the tiller number was highly significant in NE-Wheat treatment. NE treatment produced more tillers number (358.3) than FFP (274.9). Hussain et al. (1998) [13]; Haq et al. [14] also reported that number of effective tillers were increased by balanced and optimum use of fertilizer, which is in accordance to our finding. As similar to other yield attributes measured, highly significant result was found for spike length due to variation in treatments. NE treatment produce higher spike length (7.283 cm) than FFP treatment (6.04 cm). Rathi and Singh [15] suggested that nitrogen application increased spike length as compared with no fertilized plot of wheat. Highly significant result was found for filled grains per spike. NE treatment produced higher filled grains per spike (46.7) than FFP treatment (38.85). Wingham and Kemp [16] reported that spikelet numbers increased with increasing nitrogen dose due to increased rates of spikelets primordial production. Similar results have also been recorded [17].
Table 3. Effect of improved nutrient management on plant height, effective tillers, length of spike and filled grains per spike on wheat in Jhapa, Nepal.

| Treatment | Plant height at harvest (cm) | Effective tillers m⁻² | Spike length (cm) | Filled grains per spike |
|-----------|-----------------------------|-----------------------|------------------|------------------------|
| NE        | 115.50 a                    | 358.30 a              | 7.28 a           | 46.70 a                |
| FFP       | 94.70 b                     | 274.90 b              | 6.04 b           | 38.85 b                |
| LSD (0.05)| 0.08**                     | 34.34**               | 0.34**           | 2.71**                 |
| CV (%)    | 11.50                       | 16.40                 | 7.80             | 9.60                   |

**P = 0.05, level of significance, NE = Nutrient Export, FFP = Farmer Fertilizer Practice, LSD = Least Significant Difference, CV = Coefficient of Variation.

Highly significant result was found between FFP and NE-Wheat in terms of biological, straw and grain yields and harvest index as shown in Table 4. NE treatment produced higher biomass yield than FFP treatment. Ahmad et al. [18] and Shah [19] suggested that dry matter production increased with increased level of N on wheat crop which is in accordance with our finding. Similarly, straw yield was also found highly significant between NE and FFP as shown in Table 4. The higher straw yield was found in NE treatment than FFP. Straw yield is dependent on vegetative growth and found significant dry matter growth during the experimentation though the data has not shown here. Balanced and optimum use of fertilizer increased plant height, green leaves per hill, and dry matter production, which finally resulted in higher straw yield. Our findings are in similar to the findings of others [2]. There was records of significant increase in straw yield of wheat with the successive increase in N levels up to the 150 mg kg⁻¹ soil [20]. Similarly grain yield was also found highly significant between NE and FFP. NE treatment produced more grain yield (4.71 tonne ha⁻¹) than FFP (2.99 tonne ha⁻¹). NE based practices produced 58 % higher yield in comparison to FFP. The increase in grain yield is mainly due to increased radiation interception driven by a rise in growth rate, leaf area and leaf area index, which ultimately increased grain yield. Moreover, the highest grain yield is the result of increased spikes m⁻², grains per spike and 1000-grain weight, which has not been presented in this result. In a similar study done outside Nepal, the highest wheat grain yield (5168 kg ha⁻¹) was obtained, where 175:150:125 kg ha⁻¹ NPK was applied, and the lowest grain yield (2502 kg ha⁻¹) from without NPK fertilizer [21, 22]. Dobermann et al. [23] also reported the same result that NE® Rice showed an increased yield more than that of the FFP in rice crop. Acharya et al. [24] reported that NE-Rice gave higher grain and straw yields than FFP in rice, which is in accordance to our findings in wheat. Similarly, the harvest index was also found highly significant between these two treatments (Table 4). The higher harvest index was found in NE than FFP. Overlooking the literature [25], it has also been reported that harvest index was found low (49.0%) at higher N dose (40 kg N ha⁻¹ N) and higher (51.9%) at lower N dose (0 kg ha⁻¹ N), which is in accordance to our findings.

Cost of cultivation was found highly significant between NE and FFP (Table 5). NE has the higher cost of cultivation than FFP. Higher costs on NE are associated with intensive use of human labors for fertilizer charges. Similarly, gross returns was also found highly significant between NE and FFP. The result showed that higher gross returns was found in NE (NRs.1,47,979 ha⁻¹) than FFP (NRs. 1,02,265 ha⁻¹). The gross income was high on NE followed by FFP farms. The bumber production of wheat through higher fertilizer dose applied timely as per crop demand under NE resulting balanced fertilization resulted higher wheat yield and net returns. NE produced highest net returns (NRs.1,02,878 ha⁻¹) as compared to FFP (NRs. 60,562 ha⁻¹). From the experiment conducted in Haryana reported that farmers can expand their profit through Nutrient Expert®- Wheat tool over their own traditional fertilizer management practice [26].

As similar to gross and net returns, it is revealed that benefit: cost ratio was also highly significant between NE and FFP (Table 5). The highest benefit: cost ratio was found in NE (3.291) followed by FFP (2.453). Higher value of benefit: cost ratio in NE might be due to more gross returns appeared from NE which is due to higher grain and straw yields in NE wheat treatment. As per our results, the integrated use of urea and FYM at 75:25 or 50:50 ratios (N basis) had produced maximum wheat yields and was then recommended for profitable wheat grain yield [17]. As per our findings, the higher benefit-cost ratio was obtained in NE®-Wheat (2.42) over FFP (1.37) in abroad [27].

About 58 % increment in grain yield and 23 % increment in straw yield was recorded by NE over FFP (Table 5). Harvest index of NE was 38 % higher than FFP shown in Table 4. Biradar et al. [28] reported that average yield increased due to Site Specific nutrients management.

Table 4. Effect of improved nutrient management on biological yield, straw yield, grain yield (tonne ha⁻¹) and harvest index on wheat in Jhapa, Nepal.

| Treatment | BY (tonne ha⁻¹) | SY (tonne ha⁻¹) | GY (tonne ha⁻¹) | HI (%) |
|-----------|----------------|----------------|----------------|-------|
| NE        | 9.28 a         | 3.78 a         | 5.00 a         | 50.78 a |
| FFP       | 8.14 b         | 3.07 b         | 2.99 b         | 36.84 b |
| LSD (0.05)| 0.47**         | 0.18**         | 0.18**         | 3.91** |
| CV (%)    | 10.70          | 8.30           | 7.10           | 10.40 |

**Highly significant at 0.01 level and * means significant at 0.05 BY = Biological Yield, SY = Straw Yield, GY = Grain Yield, HI = Harvest Index, NE = Nutrient Export, FFP = Farmer Fertilizer Practice, LSD = Least Significant Difference and, CV = Coefficient of Variation.

Table 5. Effect of improved nutrient management on cost of cultivation, gross returns, net returns and benefit: cost ratio.

| Treatment | CC      | GR      | NR      | Re:C   |
|-----------|---------|---------|---------|--------|
| NE        | 45102   | 147979  | 102878  | 3.29   |
| FFP       | 41703   | 102265  | 60562   | 2.45   |
| LSD (0.05)| 1034** | 4977**  | 5180**  | 0.14** |
| CV (%)    | 3.60    | 6.00    | 9.60    | 7.80   |

** means highly significant at probability level at 0.01, CC = Cost of cultivation, GR = Gross returns, NR = Net returns, NE = Nutrient Export, FFP = Farmer’s fertilizer practice.
Table 6. Increment on grain and straw yields, and harvest index of wheat due to adoption of NE-Wheat over FFP in eastern-Terai, Jhapa, Nepal.

| Treatments | GY Yield difference over FFP | Increased % | SY Yield difference over FFP | Increased % | HI Yield difference over FFP | Increased % |
|------------|-----------------------------|-------------|-----------------------------|-------------|-----------------------------|-------------|
| NE         | 4.71 (+1.72)                | 58          | 3.78 (+0.71)                | 23          | 50.78 (+13.94)              | 38          |
| FFP        | 2.99                        | 3.07        |                            |             | 36.84                       |             |

GY = Grain yield tonne ha⁻¹, SY = Straw yield tonne ha⁻¹, HI = Harvest index, NE = Nutrient Expert, FFP = Farmers' Fertilizer Practice.

(SSNM) over recommended rate of fertilizer (RDF) was 35% and was 50% over FFP, which is in accordance to our findings.

4. Conclusion

Comparison of NE® - Wheat estimated attainable wheat yield and net returns given by NE®-wheat model versus actual wheat yield and net returns in farmer’s fertilizer trail. NE-based fertilizer recommendations proved to be successful in reaching the yield targets estimated by the software. Thus, NE recommendation was found better over FFP. Higher wheat with higher profitability could be obtained from NE based recommendation as it makes use of the right source of fertilizer, at right time, in right amount and in right place and fulfilled the growing demand for wheat for food and feed.

Declarations

Author contribution statement

Ram Datta Bhatta: Conceived and designed the experiments; Performed the experiments; Wrote the paper.
Lal Prasad Amgain: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.
Roshan Subedi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.
Bishnu Prasad Kandel: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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