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Research Article

Growth, productivity, physical and economic optima and yield gaps estimation in wheat (*Triticum aestivum* L.) through site specific nutrient management approaches under inner-Terai region of Chitwan, Nepal

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ABSTRACT
An on-farm field experiment was accomplished during the winter season of 2018/19 under inner Terai region at Khairahani, Chitwan for evaluating the influence of various site specific nutrient management approaches on growth, yield, optimum fertilizer dose and yield gaps of wheat (*Triticum aestivum*, L.)**.** The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications with different eight nutrient management practices: T_1- farmers fertilization practice (FFP) (52:33:18 kg NPKha^{-1}), T_2 - Blanket recommendation (BR) (100:50:25 kg NPK ha^{-1}), T_3 - SSNM-NE (110:47:46 kg NPK ha^{-1}),T4 - LCC-N+NE-P&K, T_5 - NE-N + farmers -P&K, T_6 - LCC- N + farmers–P&K, T_7 - Nitrogen Omission Plot (NOPT) + NE-P&K, and T_8 - NARC recommendation (120:60:40 kg NPK ha^{-1}). The result findings indicated that the NARC recommendation was comparatively superior over other treatments in terms of plant height, dry matter accumulation, crop growth rate and yield, but the profitability (B:C ratio) was found higher in SSNM-Nutrient Expert recommendation. The physical and economic optimum level of fertilizer for wheat obtained was 135:47.66:43.94 kg NPK ha^{-1} and 130: 47.86:43.61 kg NPK ha^{-1}, respectively. The yield gaps between farmers practice and SSNM-Nutrient Expert was found to be 110% and 41%, respectively over potential yield of wheat. Thus, it could be suggested that there is great potential to improve the yield of wheat through the NARC recommendation and the SSNM- Nutrient Expert model to raise sustained productivity and income of wheat farmers in inner-Terai region of Nepal.
Keywords: Growth, Inner-terai region, Physical and economic optima, Productivity, Site specific nutrient management, Wheat.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most staple food crop in the world and third important cereal crop of Nepal (FAO, 2019). The wheat productivity in Nepal has steadily

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increased from 2.23 Mt ha^{-1} (2007/08) to 2.84 Mt ha^{-1} (2019/20) in the last twelve years. More than 80% of wheat is grown in rice-wheat cropping pattern; in addition, it is a major winter cereal crop in Nepal (Kandel et al., 2018). It is reported that the wheat growing area in Chitwan is 5,272 ha with an average productivity of 4.4 Mt ha^{-1} (MoALD, 2018), but in contrast to the national records, the wheat yield in inner-Terai, region including Chitwan, one of the potential wheat pocket domain is decreasing lower than potential yield, recording huge yield gaps over the farmer's field yield because of poor nutrient management in farmers' field at present (Amgain *et al.*, 2020; MoALD, 2018). Nutrient imbalances, inefficient fertilizer use and large losses to the environment are blamed for the decreasing trend of yield especially over the use of nitrogen fertilizer as major and other macronutrients in minor (Amgain *et al.*, 2020; Thapa *et al.*, 2020). The proper management of nutrients is necessary for a successful crop production. Nutrient deficiencies and toxicities decrease crop health and productivity (Pandey et al., 2020).

In India and the developed world, the 'green revolution' in agriculture became successful only after the judicious management of seeds, fertilizers, irrigation water and scientific management factors (Timsina & Conner, 2001). Manures and fertilizers are the vital components of the production in any agriculture system, in which the NPK fertilizer is considered the kingpin. In smallholder intensive cropping systems of Nepal, farmers often over or under use nutrients or apply them in an imbalanced manner, at an inappropriate time, or by wrong methods (Timsina *et al.*, 2010). Such practices result in low crop productivity and economic returns and often leave a large environmental footprint of fertilizer use (Devkota *et al.*, 2018). The unavailability of the Urea Nitrogen to be applied at the time of panicle initiation and heading stage in rice of previous year and wheat growing season in this running year has created the national issues on national news portal and it is looking a great threat to the government of Nepal and forced the stakeholders to think seriously on its alternative ways. Site Specific Nutrient Management (SSNM) approach, based on principles of i) fixed yield target, ii) assessment of the indigenous nutrient supplying capacity of the soil, and iii) use of limited nutrients through NPK fertilizers will be the single strategy seems possible to solve the pertinent issue appeared at now in Nepal (Dobermann *et al.*, 2004; Majumdar *et al.*, 2017; Amgain *et al.*, 2016). The alternative SSNM approaches like LCC is the next options to the farmers. Leaf colors are used as a visual and subjective indicator of the need for N fertilizer (Dobermann *et al.*, 1996; IRRI, 2010; Pampolino *et al.*, 2012; IPNI, 2017). NE follows the SSNM guidelines for fertilizer application and split dressings, which consider the crop's nutrient demand at critical growth stages (Singh & Singh, 2003; Witt *et al.*, 2009).

Fertilizer application decisions in Nepal are usually based on farmer perceptions, which rarely apply balanced nutrition and are often resource driven rather than science driven. Peers, e.g., progressive farmers who usually have access to better knowledge, often influence the average farmer's decisions in ways that may or may not be science based (MoALD, 2018). The government's agriculture research and extension departments have developed national fertilizer recommendations for crops which provide a single recommendation for the entire country which is oversimplification of fertilization recommendation and therefore is a limitation of the approach (Timsina, 2018; Timsina *et al.*, 2018). The mechanism of promotion or dissemination of the knowledge of national fertilizer recommendation has not been very successful in reaching large numbers of farmers in Nepal. The most rigorous

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approach could be soil-test-based recommendations, however, there are no or very few soil testing facilities in Nepal and it will take years to analyze the soil samples of all the farm households with the present infrastructure and facilities. Hence, the current situation demands nutrient management recommendation guidelines for the farmers that are scientifically robust, user friendly, and simple to use.

A resource-driven fertilizer recommendation strategy would be more acceptable to farmers instead of 'one size fits all' recommendations. Establishing fertilizer recommendations suitable for smallholder farming households in Nepal still remains a challenge though there are several accesses to a science-based fertilizer recommendation in high yielding cereal crops for increasing fertilizer use efficiency (Majumdar *et al.*, 2017). Therefore, estimation of physical and economic optimum dose of fertilizer is utmost importance in major cereal crops for making the production system more profitable and sustainable. The present research eventually helps in identifying the best ways of managing the wheat nutrition through various approaches of SSNM approaches for sustained and higher wheat production in the inner-terai region of Nepal.

MATERIALS AND METHODS

Site, soil, weather and treatment details

The on-farm field experiment was conducted in the research farm of Rampur Campus, Khairahani, Chitwan (27^{o} 16' N, 84º 54' E, 228 masl) from Nov 15, 2018 to April 12, 2019. The soil at the beginning of the experiment (2018/2019) in 0–15 cm soil layer was recorded as sandy loam in texture, acidic in reaction (pH 5.1), low in organic matter (1.39%), total nitrogen (0.07%) and available phosphorus (26.48 kg ha^{-1}), but medium in available potassium (147.5 kg ha^{-1}). The total rainfall recorded during crop growth period from November to April, 2018/19 was 215.7 mm; average temperature was ranging from 11.5 to 27 ^{o}C with relative humidity of 60% to 80%.

Wheat cultivar BL-4341 (newly released cultivar in Nepal) was sown during winter season in rice–wheat cropping system. Eight fertilizer treatments were executed, consisting of different proportions of N, P_2O_5, and K_2O. Treatments imposed were : T_1- farmers fertilizer practice (FFP) (52:33:18 kg NPKha^{-1}), T_2 - Blanket recommendation (BR) (100:50:25 kg NPK ha^{-1}), T_3 - SSNM-NE (110:47:46 kg NPK ha^{-1}), T4 - LCC-N+NE-P&K, T_5 - NE-N + farmers -P&K, T_6 - LCC-N + farmers–P&K, T_7 - Nitrogen Omission Plot (NOPT) + NE-P&K, and T_8 - NARC recommendation (120:60:40 kg NPK ha^{-1}), which were laid out in Randomized Complete Block Design (RCBD) with three replications. Crop was grown with recomended package of practices wherein full dose of P and K through DAP, MOP and Urea was applied basally (Reddy & Reddy, 2009).

Growth, phenology, yield, economics, yield gaps records and statistical analysis

Growth attributes of wheat at the time of harvest (plant height, LAI, dry matter) and 50% physiological maturity was recorded, crop growth rate (CGR) was calculated from 30 DAS to the harvest stage of the crop using proper formulae (Amgain *et al.*, 2019), while yield attributes viz. effective tillers m^{-2}, filled grains spike^{-1}, thousand grain weight (g), were counted from 10 randomly selected plants of each plot. Grain, straw and biological yields (t ha^{-1}), were recorded from the net plot of 10 m^2 area and seed yield was adjusted at 14% moisture. Harvest index and sterility percentages were then calculated following the standard

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formula. Profitability analysis was done and expressed as cost of cultivation, gross and net returns, and net returns/ NRs invested (B:C ratio) on hectare basis. The physical and economic optimum fertilizer doses were estimated using the quadratic equation formula as given below.

$$Y = a + b X + c X^2$$

Where, Y is grain yield (kg ha^{-1}), X is fertilizer dose (N/P/K kg ha^{-1}) and a, b and c are constants. Constant a is known as intercept which indicate the yield level without fertilizers. Constant b otherwise known as slope provides the response rate (kg obtained per kg fertilizer applied). Constant c represents the curvature of the response line which indirectly indicates the adverse effect. In estimation of physical optimum, the response rate dY/dX is higher at lower doses of fertilizer. Maximum grain yield can be obtained at fertilizer level where response rate is zero. That is dY/dX = 0 where grain yield is maximum. But in calculation of economic optimum, it depends upon the price of fertilizer and grain. The price of grain indicate by PY and price of fertilizer (N/P/K) indicated by PX. It follows that dY/dX = PX/PY for economic optimum. The biometric data on ancillary and yield parameters were analyzed by standard statistical techniques (Gomez & Gomez, 1984). Yield gap analysis was done by bridging the yield gaps over the different treatments and presented by figures.

RESULTS AND DISCUSSION

Growth attributes

The growth attributes as plant height, LAI, dry matter accumulation at harvest and days to 50% physiological maturity of wheat has been presented in Table 1.

Table 1: Effect of site specific nutrient management practices on growth attributes and phenology of wheat in the on-farm experiment at Khairahani, Chitwan, Nepal during 2018-19

Treatments	Plant height (cm)	LAI	Dry matter accumulation (g m^{-2})	Days to 50% physiological maturity
FFP	101.20^{bc}	0.63^{ab}	1403.46^{bcd}	104.00 ^{bc}
BR	106.83^{ab}	0.75^{ab}	1532.66^{b}	109.00 ^{a}
SSNM-NE	107.20^{a}	0.68^{ab}	1641.60^{b}	107.66^{ab}
LCC-N+NE-P&K	101.03^{c}	0.63^{ab}	1119.73^{cd}	105.66^{abc}
NE-N+FFP-P&K	107.70^{a}	0.96 ^{a}	1720.13^{ab}	108.66^{ab}
LCC-N+FFP-P&K	106.86^{a}	0.82^{ab}	1466.80^{bc}	108.66^{ab}
NOPT+NE-P&K	94.60^{d}	0.40 ^{b}	1020.93^{d}	102.33^{c}
NARC Recom	109.36^{a}	0.83^{ab}	2092.53^{a}	109.33^{a}
GM	104.35	0.71	1499.733	106.91
LSD (0.05)	5.64(***)	0.47	406.37(**)	4.94
CV%	5.64	7.78	15.48	2.63

The result revealed that the significantly higher plant height (109.36 cm) was found to be for NARC recommended NPK doses, but the rest of the treatments were found to be statistically at par among each other. The minimum height was recorded for Nitrogen Omission Plot + Nutrient Expert -P &K. The leaf area index increase progressively upto 90 DAS, and, thereafter decreased at maturity with the highest leaf area index in SSNM-Nutrient Expert-N + farmers' - P&K, followed by NARC and Blanket Recommendations. The dry matter accumulation increased progressively upto maturity stage and the increase was remarkable from anthesis to harvest because of the grain formation which increased the weight of spike and marked the significantly higher dry matter at NARC recommended dose (2092.53 g m^{-2}),

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followed by LCC-N + farmers' fertilizer practice-P&K (1720.13 g m^{-2}), and SSNM-Nutrient Expert dose (1641.60 g m^{-2}). Though the physiological maturity was governed by different nutrient management practices, it was significant with average days to 50% maturity (106.91 DAS). The early anthesis was recorded for LCC-N+FFP-P&K at 59.33 days of sowing and late anthesis resulted in NR recommended at 66.66 days of sowing, which resulted almost same trend in physiological maturity too.

Crop Growth Rate

The CGR was recorded maximum for NARC recommendation which was 42.50 g $day^{-1}cm^{-2}$ followed by LCC-N + farmers P and K (20.25 g $day^{-1}cm^{-2}$) and NE recommendation (26.32 g $day^{-1}cm^{-2}$) during active grain filling stage. The minimum growth rate was recorded for Nitrogen omission plot + farmers P&K throughout the crop growth period (Figure 1).

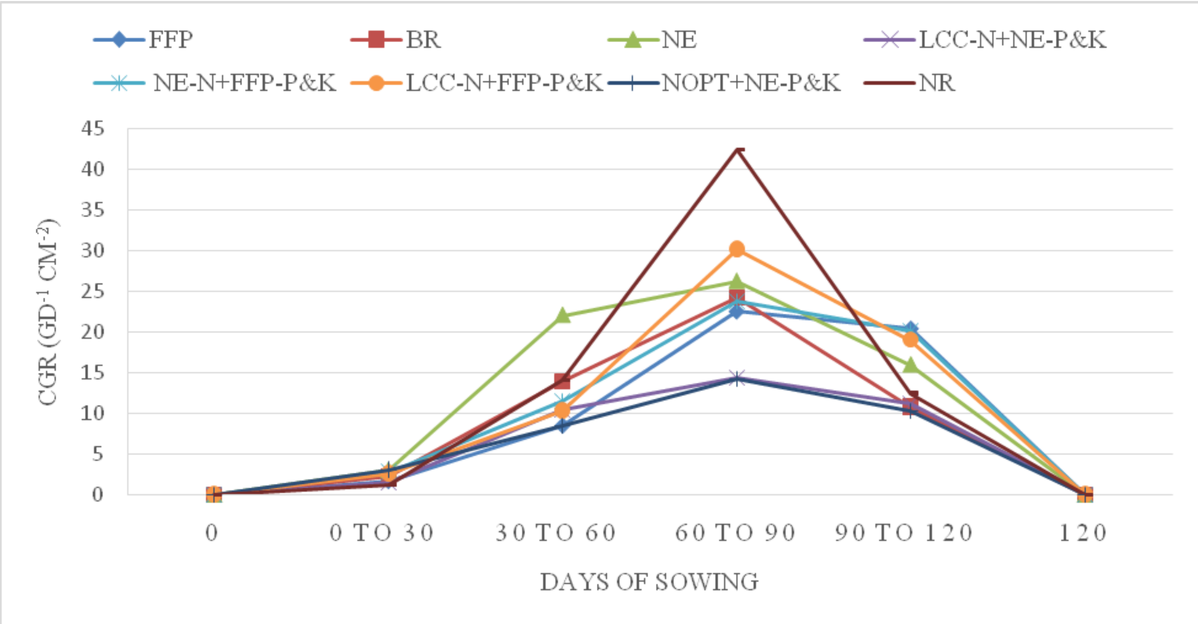

Figure 1: CGR of wheat plant (g day^{-1} cm^{-2}) as influenced by different nutrient management practices at Khairahani, Chitwan during 2018-19.

Yield attributing characters

The effective tillers m^{-2}, no. of filled grains $spike^{-1}$, 1000-seed weight (g), and sterility percentage have taken as major yield attributes of wheat (Table 2). The average effective tillers was recorded as 107.11 m^{-2}, in which the NARC based nutrient doses recorded the highest number of effective tillers (121.44 m^{-2}), followed by Blanket recommendation (118.11 m^{-2}), and SSNM-Nutrient Expert (117.33 m^{-2}) compared to other treatments. NOPT+ SSNM-NE + farmers-P&K had recorded the least number of effective tillers (82.77 m^{-2}). The average number of filled grains $spike^{-1}$ was 45.76 grains $spike^{-1}$. The highest number of grains $spike^{-1}$ was recorded under the treatment SSNM-Nutrient Expert (53.33 grains $spike^{-1}$) followed by treatment LCC-N+ farmers -P&K (51.40 grains $spike^{-1}$) and NARC recommended doses (49.73 grains $spike^{-1}$), though these were statistically at par. The minimum grains $spike^{-1}$ was recorded in NOPT + SSNM-Nutrient Expert -P&K (35.46 grains $spike^{-1}$). The average test weight was recorded 53.95g which was influenced by different nutrient management practice (Table 2). The test weight of wheat ranges from 52 g to 56 g

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which was recorded in Blanket doses and SSNM-Nutrient Expert-N+ farmers -P&K, respectively, but the remaining treatments were at par to each other.

Table 2: Effect of site specific nutrient management practices on yield attributing characters of wheat in the on-farm experimentation at Khairahani, Chitwan, Nepal during 2018-19.

Treatment	Effective tillers m^{-2}	Filled grain $spike^{-1}$	1000-grain weight (g)	Sterility (%)
FFP	95.22	43.06 ^{bcd}	54.33 ^{ab}	8.63^{abc}
BR	118.11	45.33 ^{abc}	52.00 ^{b}	12.80 ^{a}
SSNM-NE	117.33	53.33 ^{a}	53.0 ^{ab}	6.70 ^{c}
LCC-N+NEP&K	116.77	45.73^{abc}	54.66 ^{ab}	7.89^{bc}
NE-N+FFP-P&K	96.00	42.06 ^{cd}	56.00 ^{a}	10.34^{abc}
LCC-N+FFP-P&K	111.66	51.40 ^{ab}	53.66 ^{ab}	9.23^{abc}
NOPT+NE-P&K	82.77	35.46 ^{d}	53.33 ^{ab}	11.75^{ab}
NARC recom.	121.44	49.73^{abc}	54.66 ^{ab}	8.45^{abc}
GM	107.41	45.76	53.95	9.47
LSD (0.05)	NS	8.57(*)	3.9	4.66
CV %	12.72	10.69	4.13	18.0

Grain and biological yields, and harvest index

The grain yield of wheat during experimentation was found to be governed various approaches of site specific nutrient management (Table 3).

Table 3: Effect of site specific nutrient management practices on grain and biomass yields, and harvest index of wheat in field experimentation at Khairahani, Chitwan, Nepal during 2018-19.

Treatment	Grain yield at 14% moisture (t ha^{-1})	Biomass Yield (t ha^{-1})	HI
FFP	2.37 ^{cd}	9.51 ^{b}	0.19 ^{bc}
BR	2.38 ^{cd}	9.12 ^{b}	0.20 ^{bc}
SSNM-NE	3.35 ^{b}	10.78^{ab}	0.24 ^{ab}
LCC-N+NE-P&K	2.70 ^{bc}	10.04 ^{b}	0.21 ^{bc}
NE-N+FFP-P&K	3.15 ^{bc}	9.65 ^{b}	0.23^{ab}
LCC-N+FFP-P&K	3.01 ^{bc}	9.92 ^{b}	0.21^{bc}
NOPT+NE-P&K	1.55^{d}	6.75 ^{c}	0.16 ^{c}
NARC reom.	4.43 ^{a}	12.38 ^{a}	0.28 ^{a}
GM	2.87	9.77	0.21
LSD (0.05)	0.95(***)	1.7(***)	0.05(*)
CV%	18.91	9.95	13.27

The average yield recorded during the experimentation was 2.87 t ha^{-1}. The highest yield (4.43 t ha^{-1}) was recorded in NARC recommendation followed by SSNM-Nutrient Expert (3.35 t ha^{-1}) and Leaf color chart-N + farmers- P&K (3.15 t ha^{-1}). The minimum yield was recorded in the Nitrogen Omission+ SSNM-Nutrient Expert-P&K (1.55 t ha^{-1}), highlighting, N is the most critical nutrient to increase the wheat yield. The estimated yield for SSNM-Nutrient Expert was 5 t ha^{-1} under favorable climatic condition and irrigation, but due to

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spatial damage due to scanty rainfall at the earlier growth stage the estimated and expected yield range i.e. 5 t ha^{-1} of wheat variety BL4341 was not achieved. The grain yield showed the positive relation with the yield attributes like number of effective tillers m^{-2}, filled grains $spike^{-1}$. The poor status of total soil N has also marked the lesser yield under N omission plot as advocated by Thapa *et al.* (2020) in rice at Bhaktapur, Nepal.

As in grain yield, biological yield was also influenced by nutrient management practices and the maximum biomass yield was obtained in NARC recommendation (12.38 t ha^{-1}), followed by SSNM-Nutrient Expert (10.78 t ha^{-1}) and Leaf color chart-N + Nutrient Expert- P&K (10.04 t ha^{-1}). The minimum biomass yield (Table 3) was obtained in Nitrogen omission plot + SSNM-Nutrient Expert-P&K doses (6.75 t ha^{-1}). The highest harvest index of 0.28 was recorded in NARC recommended doses of nutrient, followed by SSNM-Nutrient Expert (Table 3). The lowest harvest index (0.16) was recorded in Nitrogen omission + Nutrient Expert-P&K because of variance in proportion of grain yield and biomass yield. Generally, the harvest index directly depends on the grain and biomass yields along with graded doses of fertilizer imposed as treatments. This results corroborate to the results of various authors (Gupta *et al.*, 2011; Kumar *et al.*, 2016) mentioning that biological yield increases with increase in fertilizer doses. Singh *et al.* (2007) signifies that LCC application saves the fertilizer without reduction on wheat yield. The increase in grain and straw yield with increased doses of fertilizer's might be due to improvement in growth, yield attributed characters and higher photosynthetic activity (Shrestha *et al.*, 2018; Kumar *et al.*, 2017).

Economic Analysis

The economic analysis revealed that the SSNM-Nutrient Expert recorded the best economic performance with total cost of NRs. 0.58 and gross return NRs. 1.13 lakhs ha^{-1} (Table 4).

Table 4: Effect of site specific nutrient management practices on total cost, gross revenue and B:C ratio in the on-farm experimentation at Khairahani, Chitwan, Nepal 2018-19.

Treatment	Total Cost (NRs. lakhs ha^{-1})	Gross Revenue (NRs. lakhs ha^{-1})	B:C Ratio
FFP	0.53 ^{e}	0.81 ^{cd}	1.50 ^{ab}
BR	0.56 ^{c}	0.80 ^{cd}	1.43 ^{ab}
SSNM-NE	0.58 ^{b}	1.13 ^{ab}	1.94 ^{a}
LCC-N+NE-P&K	0.58 ^{b}	0.91 ^{bc}	1.55 ^{a}
NE-N+FFP-P&K	0.58 ^{b}	1.03 ^{bc}	1.76 ^{a}
LCC-N+FFP-P&K	0.56 ^{c}	1.01 ^{bc}	1.80 ^{a}
NOPT+NE-P&K	0.55 ^{d}	0.55 ^{d}	1.00 ^{b}
NARC recom.	0.75 ^{a}	1.41 ^{a}	1.87 ^{a}
GM	0.59	0.95	1.6
LSD (0.05)	0.009(***)	0.3(**)	0.52(*)
CV%	0.91	17.89	18.4

Although the total cost and gross revenue was higher in NARC recommendation (NRs. 0.75 lakhs and NRs 1.41 lakhs ha^{-1}, respectively, the B:C ratio was maximum in SSNM-Nutrient Expert recommendation. The Farmers practice exhibited the lowest total cost (NRs. 0.53 lakhs ha^{-1}), followed by Nitrogen omission plot (NRs. 0.55 lakhs ha^{-1}), but the gross return

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was greater in farmers fertilizer practice (NRs. 0.81 lakhs ha^{-1}) over Nitrogen control (NRs. 0.55 $lakhs^{-1}$). The total cost of SSNM-Nutrient Expert was comparable to farmers fertilizer practice and LCC- N + farmers - P &K, but B:C ratio was far higher than other practices. Bhatta *et al.* (2020) and Kunwar *et al.* (2019) also showed similar result that revenue from SSNM-Nutrient Expert is higher over farmers practice and governmental recommendation in wheat under eastern terai region of Nepal. The reduction in fertilizer by application of NE over FFP enhances the profitability of wheat (Satyanarayana *et al.*, 2013; Jat *et al.*, 2013). Acharya *et al.* (2019) observed that site–specific nutrient management recorded higher profit over current farmer fertilizer practice.

Physical and economic optimum fertilizer doses

A mathematical simulation/ calculation for yield were made through interaction between the variable fertilizer doses, and yield was related by the quadratic equation. The yield and response of single fertilizer factor was obtained by dimension reducing two factors into zero in quadratic equation**.**

The quadratic equation for the various SSNM treatments is as follows:

$$Y = 12078.73+27.82\,N - 660.66\,P + 238.19\,K - 0.1028N^2 + 6.3919P^2 - 2.7168K^2$$

$$Y_N = 12078.73+27.82\,N - 0.1028N^2 \quad (P=0 \text{ and } K=0)$$

$$Y_P = 12078.73 - 660.66\,P + 6.3919P^2 \quad (N=0 \text{ and } K=0)$$

$$Y_K = 12078.73 + 238.19\,K - 2.7168K^2 \quad (N=0 \text{ and } P=0)$$

For physical optimum dose, response rate equals zero($d_Y / d_{N,P,K}=0$) and for economic optimum dose the response rate is equals to the price ($d_Y / d_{N,P,K} = P_N / P_Y$)

When P and K was coded at 0 level,

$$Y_N = 12078.73+27.82\,N - 0.1028N^2 \ldots\ldots (1)$$

From sub equation 1, when response rate is zero, the physical optimum dose of Nitrogen was obtained to be 135 kg ha^{-1} and when price ratio equals to price ratio the economic optimum dose of Nitrogen obtained was 130 kg ha^{-1}.

When N and K was coded at 0 level

$$Y_P = 12078.73 - 660.66\,P + 6.3919P^2 \ldots\ldots (2)$$

From sub equation 2, when response rate is zero, the physical optimum dose of Phosphorous was obtained to be 47.66 kg ha^{-1} and when price ratio equals to price ratio the economic optimum dose of phosphorous obtained was 47.86 kg ha^{-1}.

When N and P was coded at 0 level

$$Y_K = 12078.73 + 238.19\,K - 2.7168\,K^2 \ldots\ldots (3)$$

From sub equation 3, when response rate is zero, the physical optimum dose of potassium was obtained to be 43.94 kg ha^{-1} and when price ratio equals to price ratio the economic optimum dose of K obtained was 43.61 kg ha^{-1}.

Yield gap analysis

SSNM based approaches tested were found to be able to show higher performance in terms of grain yields and yield attributing traits. The potential yield of wheat was 5 ton ha^{-1}, but the SSNM based Nutrient Expert yields 3.35 t ha^{-1} which is 41% lesser than the potential yield. In case of farmers' fertilizer practice, the yield was obtained 2.37 t ha^{-1} which was 49% less than the SSNM based Nutrient Expert. The farmer's fertilizer practice yielded 110 % lowers than potential yield which is due to lack of NPK (Figure 2). The other major reasons for the higher yield gaps between these treatments includes poor crop establishment and management (Devkota *et al.*, 2015), declining soil fertility due to-less mineral and organic fertilizer application (Becker *et al.*, 2007), unbalanced and blanket fertilizer application

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(Devkota *et al.*, 2016), excessive soil erosion coupled with occasional heavy rainfall and intensive soil tillage (Mandal, 2002), and competing uses for crop residues and animal manures (Paudyal *et al.*, 2001).

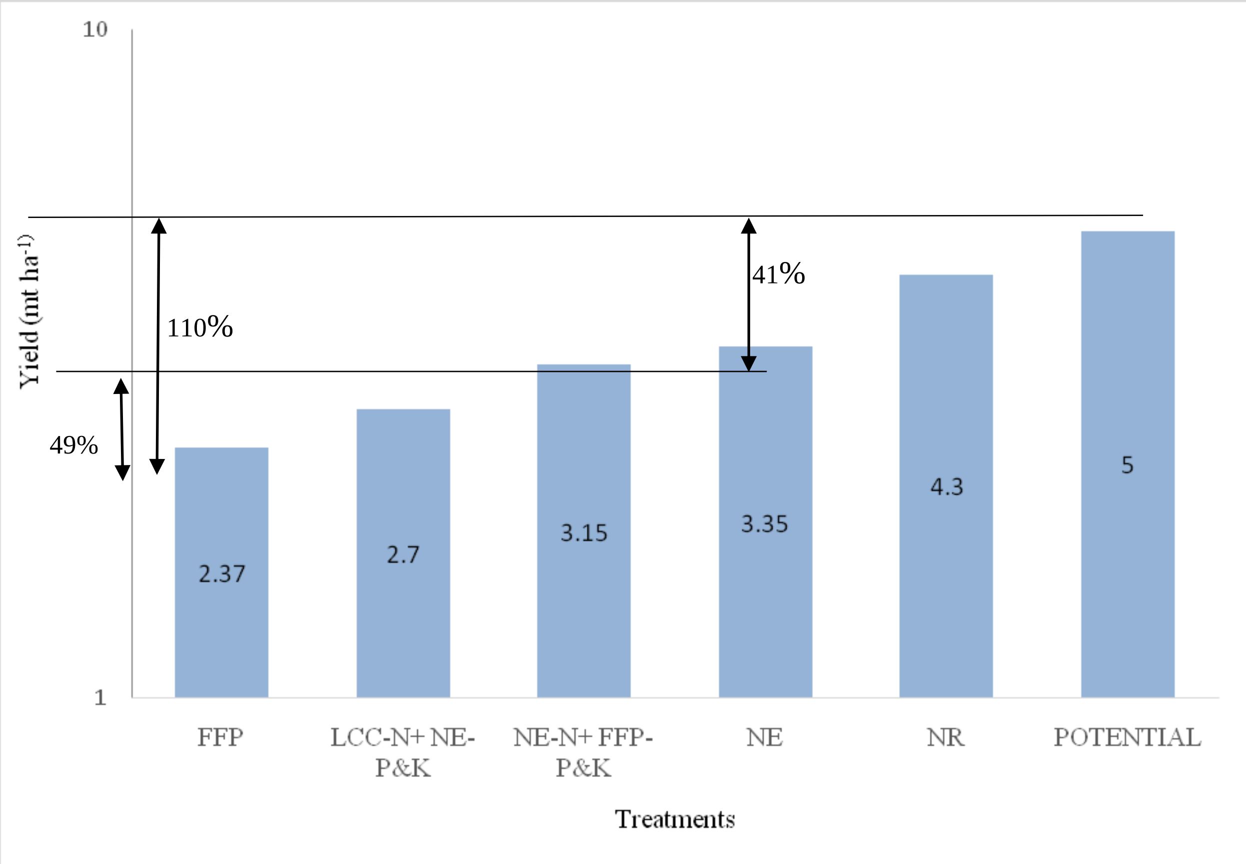

Figure 2: Yield gap analysis between various site specific nutrient management practices on farm experimentation at Khairahani, Chitwan during 2018/ 2019.

CONCLUSION

Nutrient management through optimum and timely application of fertilizers has a great potential in achieving the potential yield in cereal crops. SSNM approached based on Nutrient Expert and Leaf Color Chart identified the imbalance fertilization by farmers and helps to minimize the yield gaps and able to optimize the fertilizer application. The increase in B:C ratio plays a major factor after the adoption of SSNM tools and nutrient management practices by farmers resulting the higher chance of large scale adoption of Nutrient Expert Model as supported by this experiment. For the maximum production of wheat, estimation of the physical optimum dose and for more profitability, the economic optimum dose of fertilizer could be recommended in Nepalese context. Nepalese farmers would be able to significantly improve the yield of wheat and also raise their income through the use of site-specific fertilizer recommendation generated by NE and, hence such approaches should be promoted in the Terai and inner-Terai region where there is big bowl of production of major cereals including wheat.

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Authors' Contributions

SM conducted and accomplished this thesis as the post-graduate student, while LPA as a major supervisor designed the proposal and helped to architect this research manuscript as a part of the thesis of SM.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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