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Research Article

ESTIMATION OF NATIVE NUTRIENT SUPPLYING CAPACITY OF SOIL FOR IMPROVING WHEAT (*Triticum asestivum* L.) PRODUCTIVITY IN CHITWAN VALLEY, NEPAL

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Abstract

Three field experiments were conducted at farmer's field of Torikhet, Gopaljung and Kalyanpur of Chitwan Valley, Nepal during Nov 2011-April 2012 to assess N, P and K supplying capacity of soil. Each experimental site consists of four replications and five treatments laid out in RCB design. Among the five treatments, -N, -P and -K were set to estimate the inherent N, P and K supplying capacity of soil respectively. Highest uptake of N (100 Kg ha^{-1}), P (21 Kg ha^{-1}) and K (84 Kg ha^{-1}) by wheat and highest native N (41 Kg ha^{-1}), P (18 Kg ha^{-1}) and K (72 Kg ha^{-1}) supplying capacity of soil was recorded at Kalyanpur. Similarly, N, P and K required to produce one Mg of wheat grain was found highest in Kalyanpur. Based on the yield obtained in fully fertilized plot, target yield of 5 Mg ha^{-1} was set. Finally, N, P and K fertilizer needed were calculated on the basis of nutrient required for target yield, NPK supplying capacity of soil and recovery efficiency of NPK from fully fertilized plot. To obtain the target grain yield of 5 Mg ha^{-1}, N: P: K at differential rate of 140: 30.5: 57 Kg ha^{-1}, 140:27:53 Kg ha^{-1} and 120:22.5:38.5 Kg ha^{-1} has to be supplied from external source in Torikhet, Gopaljung and Kalyanpur respectively. This research outcome strengthens the fact that spatial variability for soil nutrient supplying exist across the farmer's field. So it is necessary to estimate that variability for improving wheat productivity.

Key words: N, P, K supplying capacity; nutrient uptake; Target yield; recovery efficiency

Introduction

In south Asia, Rice- wheat production systems occupy about 13.5 million ha and among which wheat accounts for 42 % on area basis, accounting for quarter to third of total wheat production (Ladha *et al.*, 2000). Wheat is one of the major sources of food grain in Nepal which contributes 7.14% to agricultural gross domestic products (MoAC, 2011) and has maintained the balance between food supply and population growth. However, recent evidence shows that wheat yield is either stagnant or decreasing (USAID, 2009). Declining soil fertility and loss of soil organic matter are among the major reason contributing to this stagnant yield. Research conducted in many Asian countries has demonstrated blanket (fixed-rate, fixed-time) fertilizer recommendations is being made leading to the poor nitrogen use efficiency and unbalanced P and K supply (Dobermann *et al.*, 1998; Olk *et al.*, 1999; Ladha *et al.*, 2003; Pathak *et al.*, 2003). In case of Nepal, in eastern and western Chitwan, N and P content of soil are low and the yield declination from 2.83 Mg ha^{-1} to 2.2 Mg ha^{-1} has been reported (Gairhe and Shah, 2005). Similarly, Yield gap between potential yield and farmers yield and between research station and farmers field were found to be 3.15 Mg/ha and 1.65 Mg/ha respectively (Amgain and timsina, 2004). Quantification of soil capacity to supply major nutrients N, P, K is the pre-requisite for increasing yield and nutrient use efficiency. A large variability in soil nutrient supplying capacity exists among field and recommended doses of fertilizer may not be suitable in all fields (Regmi, 2002). Individual field has to be assessed for their nutrient supplying capacity so that fertilizer required for certain targeted yield can be developed. The soil nitrogen supply is the best determined from crop nitrogen uptake in N omission plots where other nutrients are applied in sufficient amount so that plant growth is limited only by nitrogen supply (Witt and Dobermann, 2002). The omission plot technique is a useful tool to quantify soil nitrogen supply (Stalin *et al.*, 1996; Adhikari *et al.*, 1999). Similarly, other primary nutrients P and K can also be best estimated using the same omission plot technique. Therefore, in this study attempt was made to quantify native nutrient supplying capacity of soil for wheat and assess the fertilizer rate requirement based on soils nutrient supplying capacity, target yield and total nutrient uptake by wheat crop at harvest.

Materials and methods

The proposed field study was conducted in three sites, Torikhet, Gopaljung and Kalyanpur of Chitwan valley, Nepal during Nov 2011- April 2012. The experiment was laid out in RCB design with four replications and five treatments, –N i.e. (PK+Zn+B), –P i.e. (NK+Zn+B), –K i.e.(NP+Zn+B), – (B and Zn) i.e. (+NPK) and full fertilization (N, P, K, B and Zn). Each individual plot size was 5m×3m. The soil texture was Loamy to sandy loam with low soil available N (0.06 to 0.1%), low P (15.3 to 22.7 Kg ha^{-1}), low to medium exchangeable K (67.8 to 80.5 Kg ha^{-1}) , Low B (0.53 to 0.92 mg Kg^{-1}) and Zn (0.56 to 0.68 mg Kg^{-1}). Similarly, Soil was slightly acidic to neutral with pH (5.8 to 7.1) and organic matter content (2.09 to 3.21%). Vijaya variety of wheat was used as test crop and NPK was applied 50% more than the recommended dose i.e. (150:32.5:62.5 Kg NPK ha^{-1}) in which half dose of N, full P and K together with 1 Kg B ha^{-1} and 25 Kg $ZnSO_4$ ha^{-1} were applied at sowing. Rest 50% of N was splitted equally at crown root initiation (CRI) stage after first irrigation and heading stage after second irrigation. Urea, single super phosphate, muriate of potash, $ZnSO_4$ and Borax were used as the source of N, P, K, Zn and B respectively. Sowing was done on 27th November 2011 and crop from 6m^2 net plot areas was harvested manually on 10th April, 2012. Plant samples were collected randomly excluding border plants from each plot for plant analysis. Soil samples were collected diagonally from three spots of each plot at a depth of 0-20 cm using tube auger and composite sample was prepared which was air-dried, ground and sieved through 2 mm sieve for analysis. Soil samples were analyzed for Texture, Organic matter, pH, N, P_2O_5 and K_2O, B and Zn to determine initial and residual physicochemical properties of soil. Plant samples were analyzed for NPK concentration and Native nutrient supplying capacity was calculated using following formula.

$$\text{Nutrient uptake (Kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x yield (Kg ha}^{-1}\text{)}}{100} \qquad \textbf{(eqn 1)}$$

$$\text{Grain yield produce per Kg of nutrient uptake} = \frac{\text{Grain yield (Kg ha}^{-1}\text{)}}{\text{Total nutrient uptake (Kg ha}^{-1}\text{)}} \qquad \textbf{(eqn 2)}$$

$$\text{Recovery efficiency of NPK applied} = \frac{\text{TNU in [fertilized plot (Kg ha}^{-1}\text{)} - \text{control plot (Kg ha}^{-1}\text{)]}}{\text{Nutrient applied in fertilized plot}} \times 100 \qquad \textbf{(eqn 3)}$$

Where, GY=Grain Yield TNU = Total Nutrient (N, P, K) uptake (Kg ha^{-1})

Target yield was set as maximum yield obtained from fully fertilized plot of the study sites. Considering the target yield, nutrient required to produce per Mg wheat grain and efficiency factor, the nutrient required at different sites were calculated.

$$\text{Fertilizer required (N or P or K)} = \frac{\text{Nutrient required for target yield} - \text{INS}}{\text{Recovery efficiency}} \qquad \textbf{(eqn 4)}$$

Where, INS= Indigenous (N or P or K) supplying capacity of soil

To analyze the data, MSTAT-C statistical computer package was used and mean were separated at 5% level of significance.

Results and discussion

Effects on soil available NPK

Soil N, P and K at crop harvest varied significantly between sites (Table 1). The highest soil N (0.08%), P (28 Kg ha^{-1}), K (77 Kg ha^{-1}) was recorded in Kalyanpur while the lowest N (0.06%) and K (69 Kg ha^{-1}) was recorded from Torikhet. Higher residual soil NPK of Kalyanpur might be due to high initial level of NPK in soil. In addition to this high amount of organic matter was present, which upon mineralization contributed to additional N. An effect of nutrients combination on soil NPK was found to be highly significant. Residual N 0.074%, 0.075%, 0.076% and 0.075% recorded from –P, –K, – (B and Zn) and fully fertilized plots were statistically similar to each other whereas N omitted plot resulted in lowest soil N (0.057%). Significantly low nitrogen in soil of –N plot might be mainly due to exclusion of N fertilizer. Besides this high removal of native soil N further reduced the amount of residual soil N. The highest soil P (32 Kg ha^{-1}) and K(89 Kg ha^{-1}) were recorded from –N plot whereas the lowest soil P (15 Kg ha^{-1}) and K(54 Kg ha^{-1}) from –P and –K plots respectively. Higher soil P and K from –N plot might be due to significantly low biomass production severely restricted by nitrogen omission which in turn resulted in low P and K uptake. This result was in accordance with the findings of Tendon and Sekhon, (1988) who reported application of nitrogen and phosphorus resulted in 145% increase in potassium uptake as compared to control.

Effects on crop NPK uptake

NPK uptake by aboveground biomass varied significantly among the sites (Table 1). The highest N (100 Kg ha^{-1}), P (21 Kg ha^{-1}) and K (84 Kg ha^{-1}) uptake were recorded from Kalyanpur. The lowest N (87 Kg ha^{-1}) and P (16 Kg ha^{-1}) uptake were from Gopaljung whereas the lowest K (74 Kg ha^{-1}) was from Torikhet. These variations in N, P and K uptake across the study sites indicates that reserve pool of soil N, P and K is not constant in all farmers field and it varies greatly according to cultivation practices and field management practices. Effect of nutrients combination on N uptake by wheat was highly significant. The highest N uptake (118 Kg ha^{-1}) was observed from fully fertilized plot. The higher uptake of N from fully fertilized plot might be due to increase in balanced nutrient concentration and better plant growth. N uptake could be enhanced with increased P applications (Jiang *et al.* 2006) and K application also significantly helped uptake of N in straw as well as in wheat grain (Saifullah *et al.* 2002). The lowest N(31 Kg ha^{-1}), P(7.5 Kg ha^{-1}) and K(33 Kg ha^{-1}) uptake were recorded in –N plot suggesting that N strongly limits the optimum growth of wheat which leads to low biomass production and due to this crop can't make full utilization of P and K present in soil.

Indigenous nutrient (NPK) supplying capacity of soil

Soil nutrient supplying capacity for plant was estimated from the field using the omission plot technique. Individual farms differ in terms of NPK supplying capacity (Table 2). The highest N (41 Kg ha^{-1}), P (17.7 Kg ha^{-1}) and K (72 Kg ha^{-1}) were supplied by soil of Kalyanpur whereas Gopaljung soil supplied lowest amount of N (24 Kg ha^{-1}) and P(13.4 Kg ha^{-1}). This difference in N, P and K supplying capacity of soil across various sites might be due to different techniques of field management across the sites as well as variation in soil physical and chemical properties among these sites.

Table 1.Effect of sites and nutrients combination on soil N, P and K and Crop N, P and K uptake at various study sites of Chitwan Valley, Nepal, Nov 2011- April 2012

Treatments	**Nitrogen (%)**	**Available Phosphorus (Kg ha^{-1})**	**Exchangeable Potassium (Kg ha^{-1})**	**Crop Uptake (Kg ha^{-1})**		
Study Sites				**Nitrogen**	**phosphorus**	**Potassium**
Torikhet	0.06±0.02^{c}	25±6.4^{b}	69±13.2^{b}	89 ± 31^{a}	18 ± 5.8^{b}	68±24^{c}
Gopaljung	0.07±0.01^{b}	23±5.7^{b}	70±13.4^{b}	87 ± 33^{b}	16 ± 5.5^{b}	74±25^{b}
Kalyanpur	0.08±0.01^{a}	28±5.4^{a}	77±13.3^{a}	100 ± 31^{a}	21 ± 7.0^{a}	84±23^{a}
LSD	0.006	1.6	5.3	3.3	0.9	2.7
Nutrient combination						
PK+ Zn +B **(-N)**	0.06±0.01^{b}	32±1.7^{b}	89±4.9^{b}	31 ± 8^{d}	8.0 ± 1.6^{d}	33±7.5^{d}
NK+ Zn +B **(-P)**	0.07±0.01^{a}	15±2.4^{b}	75±6.8^{b}	97 ± 9^{c}	15 ± 2.0^{b}	91±7.5^{b}
NP+ Zn +B **(-K)**	0.08±0.02^{a}	26±2.9^{b}	54± 8.3^{b}	105 ±11^{b}	23 ± 3.2^{c}	60±9.0^{c}
NPK **(- Zn and B)**	0.08±0.01^{a}	26±3.4^{b}	73±12.1^{b}	108 ± 9^{b}	22 ± 3.2^{b}	93±5.6^{b}
NPK +Zn +B **(+ all)**	0.08±0.01^{a}	25±4.0^{b}	72±5.5^{b}	118 ± 9^{a}	79±5.8^{a}	100±7.6^{a}
LSD	0.008	2.0	6.8	4.3	1.2	3.5
C.V (%)	10.6	9.8	11.4	5.6	8.8	5.7

Means followed by the same letter(s) in a column are not significant at 5% level as determined by LSD.

Nutrient (NPK) required per Mg of wheat grain

Nutrient required to produce one Mg of grain was calculated on the basis of nutrient uptake and grain yield in fully fertilized plot (Table 2). Highest N uptake (22.1 Kg) was at Kalyanpur to produce one Mg of wheat grain. Meanwhile, 21.6 Kg N was required to produce same amount of grain in both Gopaljung and Torikhet. P required to produce one Mg of grain was highest (4.9 Kg) in Kalyanpur followed by 4.3 Kg in Torikhet. The lowest (3.8 Kg) was required to produce one Mg grain in Gopaljung. Highest K uptake to produce one Mg of wheat grain (19.1 Kg) was from Kalyanpur. Results obtained in this experiment were in accordance with Pathak *et al.* (2001) who reported 15.2-47.8, 2.5-7.6 and 10.4-54.6 Kg NPK required for producing one Mg of wheat grain. Nutrient requirement per Mg provides guideline to calculate the NPK required for determining a certain targeted yield.

Target yield

Based on the yield obtained in fully fertilized plot 5.27, 5.32 and 5.55 Mg/ha from Torikhet, Gopaljung and Kalyanpur respectively, a target yield of 5 Mg/ha was set in all three locations (Fig 1).

Nutrient (NPK) recovery efficiency of crop

There was variation among sites in apparent NPK recovery efficiency from fully fertilized plot (Table 3). The highest fraction of applied N (0.6 Kg N Kg^{-1}) was recovered from Gopaljung which was followed by 0.57 Kg N Kg^{-1} recovery from both Kalyanpur and Torikhet. Better fraction of N recovery in Gopaljung might be due to optimum soil condition conducive for better N utilization. From Kalyanpur, highest fraction (0.29 Kg P Kg^{-1}) of applied P was recovered while recovery fraction was 0.24 Kg P Kg^{-1} and 0.21 Kg P Kg^{-1} from Torikhet and Gopaljung respectively (Table 2). At the same time the highest fraction (0.64 Kg K Kg^{-1}) of applied K was recovered from farmer field of Torikhet.

Table 2. Indigenous NPK supplying capacity (Kg ha^{-1}) of soil and Nutrient NPK (Kg) required for producing one Mg of wheat grain in various study sites of Chitwan Valley, Nepal, 2011-2012

	Native Nutrient supplying capacity of soil (Kg ha^{-1})			**Nutrient NPK (Kg) required for producing one Mg of wheat grain**		
Farmers Field	N	P	K	N	P	K
Torikhet	28.9 ± 4.7	14.7 ± 1.7	51.7 ± 2.7	21.6 ± 0.6	4.4 ± 0.3	17.5 ± 0.54
Gopaljung	24.1 ± 5.5	13.4 ± 1.6	61.2 ± 4.5	21.6 ± 1.6	3.8 ± 0.2	18.9 ± 0.5
Kalyanpur	41.3 ± 4.2	17.5 ± 2.2	72 ± 5.5	22.1 ± 0.95	4.8 ± 0.2	19.1 ± 0.9

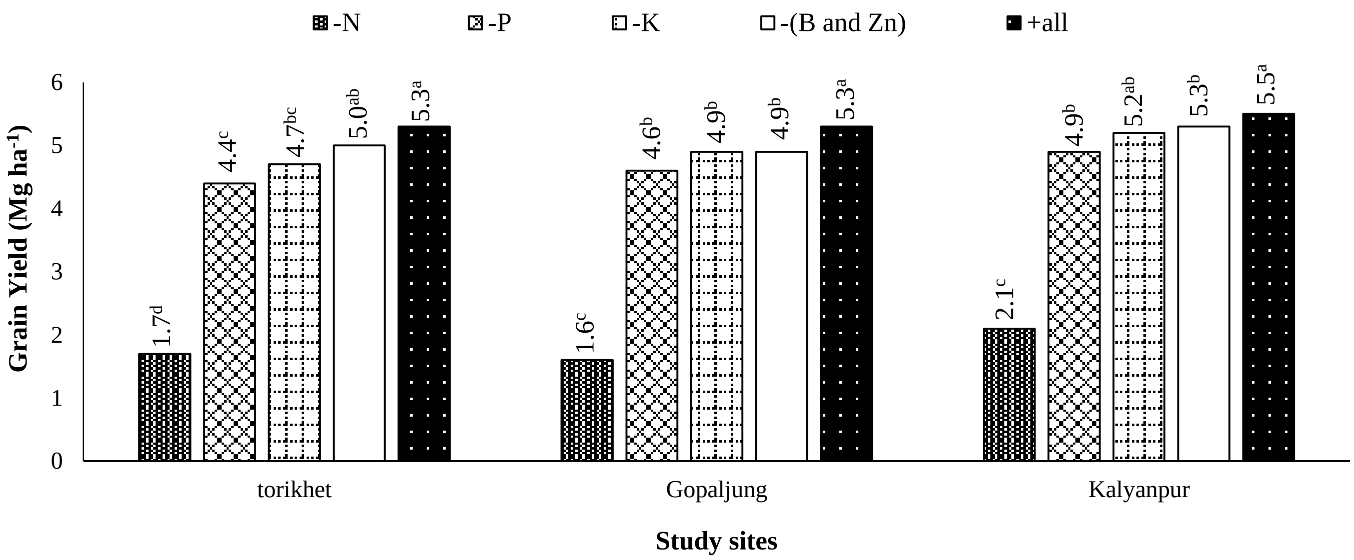

Fig 1: Effects of Nutrient omission on grain yield of wheat at various study sites of Chitwan Valley, Nepal, Nov 2011- April 2012

Table 3.Recovery efficiency of NPK from full fertilized plot and NPK required for acquiring target yield of wheat grain at various study sites of Chitwan Valley, Nepal, 2011-2012

	Recovery efficiency of NPK from full fertilized plot			**NPK required for acquiring target yield (Kg)**		
Farmers Field	**Kg N Kg^{-1}**	**Kg P Kg^{-1}**	**Kg K Kg^{-1}**	**N**	**P**	**K**
Torikhet	0.57 ± 0.02	0.24 ± 0.04	0.64 ± 0.01	140 ± 4.5	31 ± 2.3	57 ± 5.0
Gopaljung	0.60 ± 0.05	0.21 ± 0.03	0.63 ± 0.06	140 ± 6.2	27 ± 1.7	53 ± 4.3
Kalyanpur	0.57 ± 0.02	0.29 ± 0.06	0.61 ± 0.07	120 ± 3.4	23 ± 2.5	39 ± 5.6

Note: P should be multiplied by 2.29 to convert into P_2O_5 and K by 1.2 to convert into K_2O

Fertilizer NPK calculation

There was variation among sites for amount of NPK to be applied from fertilizer source (Table 3). The highest N (140 Kg) will have to be supplied in Torikhet and Gopaljung and lowest in Kalyanpur (120 Kg) to obtain the target yield. Similarly highest P (31Kg) and K (57 Kg) will have to be supplied in Torikhet whereas Lowest P (23 Kg) and K (39 Kg) has to be supplied in Kalyanpur. Lowest amount of NPK has to be supplied from fertilizer source in Kalyanpur mainly because of high native nutrient supplying capacity of soil.

Conclusion

From this research it has been clear that site to site variation for nutrient supplying capacity exist. Farmers manage their field differently, so large variation was seen even in small area. Initial soil analysis showed wide range of variation in chemical properties of soil across the sites which had differential impact on crop growth. Nitrogen was found to be most limiting nutrient for wheat growth followed by phosphorous and potassium in all sites. In order to maintain soil fertility and reach the target yield of wheat, Kalyanpur site needs less addition of NPK than two other sites due to its higher nutrient supplying capacity. Overall it can be concluded that spatial variability for soil nutrient supplying exist across the farmer’s field so it is necessary to estimate that variability for increasing wheat productivity.

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