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Research Article

SITE-SPECIFIC NUTRIENT MANAGEMENT FOR RAINFED MAIZE IN WESTERN MID-HILLS OF NEPAL

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Abstract

On-farm experiment was conducted in eight farmers' field, of Khasyoli village development committee (952 to 1415 masl), Nepal, from April to September, 2011 to address the major constraint (nutrient management) to maize production through site-specific nutrient management (SSNM) as this approach is popular among scientists. The experiment comprised three nutrient omission plots (0N, 0P, and 0K), an ample NPK plot, and a farmers' fertilization practice (FFP) plot, arranged in randomized complete block design. Farmers planted open pollinated variety (*Manakamana-3*) and managed in their way. Field-specific NPK application rates were calculated by considering nutrient demand, indigenous NPK supply and recovery efficiency of fertilizers. Grain yield in FFP (2.32 Mg/ha) and 0N (1.79 Mg/ha) plots differed significantly from each other and rest of the treatments, but was statistically similar among 0P (3.18 Mg/ha), 0K (3.40 Mg/ha) and ample NPK (3.38 Mg/ha) plots. Post-harvest grain and stover analysis revealed that indigenous NPK supply (20-71 kg N, 19-68 kg P_2O_5 and 51-164 kg K_2O/ha) of soil vary among the farmers' field. Moreover, soil was poor in indigenous N supply (42 kg/ha), but rich in indigenous P_2O_5 (35 kg/ha) and K_2O (90 kg/ha) supply, on an average. As per the principles of SSNM, the initial fertilizer recommendation made can vary from 40-222 kg N, 0-93 kg P_2O_5, and 0-50 kg K_2O/ha. On an average, farmers may apply no or lower dose of P_2O_5 (18 kg/ha) and K_2O (3 kg/ha) but need to significantly increase dose of N (143 kg/ha) fertilizer for enhancing soil and maize productivity.

Key words: site-specific nutrient management; indigenous nutrient supply; nutrient use efficiency; rainfed maize

Introduction

Maize is the second most important cereal crop after rice in Nepal, used not only as a staple food, but also as a major component of feeds and fodder for the farm animals. However, there is wide gap among the potential yield (5 Mg/ha), attainable yield (3.5 Mg/ha), and the actual yield (2.03 Mg/ha) under farmer's situation for open pollinated varieties in Nepal (Ojha, 2006).

Maize is produced under low N conditions (McCown *et al.,* 1992) because of low N status of tropical soils, low N use efficiency, high price ratios between fertilizer and grain, limited availability of fertilizer, and low purchasing capacity of farmers (Banzier *et al.,* 1997). In addition, the recovery of applied N in rainfed maize is very low due to various losses and poor crop management practices. Moreover, the application of diammonium phosphate (DAP) and potash is negligible in western mid-hill region of Nepal (Paudyal *et al.,* 2001).

The existing fertilizer recommendation is based on blanket recommendation which assumes that the need of a crop for nutrients is constant over time and large areas. However, the need for supplemental nutrients vary greatly among fields, seasons, and years (Ladha *et al.,* 2000) and a blanket dose of fertilizer will not fit to all fields. Therefore, quantification of the INS of soil for major nutrients N, P, and K is a pre-requisite to increase nutrient use efficiency and maize yield (Dobermann and White, 1999).

Site specific nutrient management is a plant based approach for supplying crops with nutrients in right amount and time. It strives to enable farmers to adjust fertilizer use dynamically to make up the deficit in nutrient needs between that required by a high-yielding crop and nutrient supply from naturally occurring indigenous sources (i.e. soil, crop residues, manures, and irrigation water).

Materials and Methods

A study consisting of two parts, field survey and on-farm experiment, was conducted to address the major constraint and study SSNM to rainfed maize in Khasyoli village development committee (952-1415 masl) of Palpa district located in the mid-hill region of Western Nepal from April to September, 2011. Based on the result of field survey, nutrient management was found to be the major constraints to productivity of rainfed maize. Field experiment was conducted in eight farmers' *Bari* land (unbunded slopy uplands) located at a latitude and longitude of $27^0 52'$ N and $83^0 27'$ E and altitude between 952-1415 masl to address the constraint, through SSNM approach.

The experimental site received total rainfall of 1230.60 mm during experimentation period which is about 96% of total annual rainfall in 2011. The mean maximum and minimum temperature during experimental period were 29.78 ^{0}C and 19 ^{0}C, respectively. The physical and chemical properties of soil at two depths (0-25cm and 25-50 cm) were analyzed before sowing of maize. The soil was found to be acidic (5.3±0.5) with low organic matter content (2.6±0.7%) and available N (0.1%), but rich in available P_2O_5 (101 kg/ha) and K_2O (495 kg/ha).

The on-farm experiment comprised of three nutrient omission plots (N omission, P omission, and K omission), a farmer's fertilization practice plot, and an ample NPK plot arranged in a simple randomized complete block design. Individual plot sizes were 6m x 6m. The maize open pollinated variety, Manakamana-3, was sown with seed rate 25 kg/ha. The plant geometry was maintained at 75 cm × 25 cm. Fertilizer rate for omission plots was 156:78:52 kg NPK/ha, while for FFP plot was 50:22:4 kg NPK/ha Urea was used as the N-source, with basal application (50%) at the time of sowing and side dressing (50%) just before emergence, dibbled 5 cm deep as band along the maize row. For the plots with P application, single super phosphate (SSP) was the source of P except for FFP, where DAP was the source of N and P. Murat of potash (MOP) was used as the source of K in all the plots, applied as basal at the time of sowing.

The research followed farmer's crop management practices which included thinning, gap filling, first weeding and hoeing at 30 days after sowing (DAS) and second weeding, hoeing and earthing-up at 60 DAS. Grain and stover were harvested at physiological maturity and analyzed for N, P_2O_5, and K_2O content as suggested by Varley (1996). Observation were recorded for plant height at harvest, final plant population, barrenness, grains per cob, thousand kernel weight, shelling percentage, grain yield at 15% moisture, stover yield, biomass yield, grain stover ratio and harvest index and subjected to analysis of variance (ANOVA) using MSTAT-C software. Mean separation was done by Duncan's Multiple Range Test (DMRT). Social data analysis was done using SPSS 16.0 software. Interpretation of result was done by Pearson Correlation. Indigenous NPK supply was evaluated using omission plot technique. Agronomic, recovery, physiological, internal efficiency, and partial factor productivity for N, P, and K were calculated using standard formula. Field-specific fertilizer nutrient (NPK) requirement was calculated considering the nutrient demand, INS of soil, and recovery efficiency of fertilizer NPK.

Results and Discussion

Effect of nutrient omission on yield of maize

Based on the analysis of field data, plant height at harvest, barrenness (%), number of grains per cob, shelling percentage, grain yield, and stover yield differed statistically among the treatments showing low (0N and FFP) and high productive (0P, 0K, and ample NPK) distinctive groups. Grain yield in FFP (2.32 Mg/ha) and 0N (1.79 Mg/ha) plots differed significantly from each other and from rest of the treatments, but was statistically similar among 0P (3.18 Mg/ha), 0K (3.40 Mg/ha), and ample NPK (3.38 Mg/ha) plots (Table 1).

Table 1: Effect of nutrient omission on growth, yield attributes and yield of maize in Khasyoli VDC of Palpa district, 2011

Treatments	**Plant height at harvest (cm)**	**Barrenness %**	**GPC**	**TKW (g)**	**SP**	**Grain yield (Mg/ha)**	**Grain nitrogen uptake**
FFP	205^{ab}	2.8^{a}	237^{b}	296	73.6^{a}	2.32^{b}	23^{b}
0 N	194^{b}	2.9^{a}	196^{c}	274	70.1^{b}	1.79^{c}	22^{b}
0 P	208^{a}	1.4^{b}	296^{a}	300	74.9^{a}	3.18^{a}	40^{a}
0 K	**214^{a}**	1.3^{b}	**315^{a}**	**311**	74.8^{a}	**3.40^{a}**	41^{a}
Ample NPK	213^{a}	1.1^{b}	303a	306	74.9^{a}	3.38^{a}	38^{a}
LSD (0.05)	13.8*	0.6**	31.8**	31.1(NS)	2.8**	0.5**	14.6
SEM ±	4.8	0.2	10.9	10.7	0.9	0.17	10.8
CV%	6	35	11	10	4	18	22
Grand mean	207	1.9	269	298	73.6	2.8	66

*= Significant ($p<0.05$), **= Significant (<0.01), LSD= Least significant difference, GPC= Grains per cob, TKW= Thousand kernel weight, SP= Shelling percentage, NS= Non-significant, Means with common letter within a category are not-significant ($p<0.05$) by DMRT

Table 2: Correlation between grain yield and different parameters

	Plant height	**Barrenness (%)**	**Grains per cob**	**TKW**	**SP**	**GNU**
Grain yield	0.95^{*}	-0.95^{*}	0.99^{**}	0.93*	0.92^{*}	0.98**

TKW= Thousand kernel weight, SP= Shelling percentage, GNU= Grain nitrogen uptake

Table 3: Effect of nutrient omission on total nitrogen, phosphorus and Potassium uptake

Treatment	Total Nitrogen Uptake	Total Phosphorus Uptake	Total Potassium Uptake
FFP	45^b	23^c	53^c
0 N	42^b	18^c	47^c
0 P	75^a	34^b	99^b
0 K	77^a	44^{ab}	89^b
Ample NPK	87^a	51^a	132^a
LSD (p= 0.05)	14.6	10	23.5
SEM ±	10.8	3.5	8
CV %	22	29	27
Grand mean	66	34	84

Yield of maize grain involves the cumulative effect of a large number of components and metabolic processes that act with varying intensity throughout the plant's life cycle (Gungula *et al*., 2007).The highest grain yield in 0K plot could be due to highest final plant height (214 cm), number of grains per cob (315), and thousand kernel weight (311 g), and lowest barrenness percentage (1.5%), suggesting that the improvement in the yield attributes might have increased the grain yield. This could be justified by the positive linear correlation between grain yield and plant height (0.95*), and number of grains per cob (0.99**), and thousand kernel weight (0.93*) and negative correlation between grain yield and barrenness percentage (-0.95*) (Table 2).

Further, highest GNU could also be another reason for the highest yield of maize under 0K plot. This has also been verified from the strong positive correlation between grain yield and GNU (0.98**) (Table 2). Lemcoff and Loomis (1986) also reported that application of ample amount of N increases N uptake which facilitates more photosynthetic activity and more partitioning of dry matter to the ears, consequently increase in yield components and grain yield. This forms the basis for high yield under high N availability. Moreover, luxury consumption of K in ample NPK plot indicates that the native supply of K was enough to support K requirement of maize and farmers in the region may apply no or lower dose of K fertilizer.

The at par grain yield among 0P, 0K, and ample NPK, where ample of N was applied but lowest in 0N plot indicates N application cannot be substituted and has highest contribution in maize yield. It could be due to high effect of N on chlorophyll formation, photosynthesis and assimilate production because nitrogen stress reduces crop photosynthesis by reducing leaf area development and leaf photosynthesis rate by accelerating the leaf senescence (Diallo *et al*., 1996). Moreover, under N deficiencies, a considerably large proportion of dry matter is partitioned to roots than shoots, leading to reduced shoot/root dry weight ratio (Rufty *et al*., 1988) and consequently the grain yield. Another strong reason might be due to low indigenous N supply capacity, as the soil of sloppy land is prone to soil and nutrient erosion.

The lower grain yield of maize in FFP in study site than average yield in western mid-hills (2.7 Mg/ha) as reported by Paudyal *et al.* (2001) could be due to improper use of several crop management related practices, mostly the lower dose of fertilizer application. It indicates that there is great scope to increase actual yield under FFP through the application of higher fertilizer (especially N) dose.

Estimating nutrient required for target yield

Target yield is considered to be 70-80% of the potential yield (Witt and Pasuquin, 2007) for irrigated maize. Accordingly, the target yield for irrigated maize variety Manakamana-3 will be 4.2 Mg/ha as the potential yield is 5.6 Mg/ha (NARC).However, there was rainfed condition in the research site. So, the highest yield of the research plot (3.5 Mg/ha) was considered as the target yield. Nutrient consumed per Mg of maize grain was calculated to be 23.55, 11.00, and 26.25 kg NPK, respectively, while Cooke (1985) reported 27.4, 4.8, and 18.4 kg NPK requirement per Mg of grain yield, respectively. N consumed was found to be low because the INS of Bari land was low. P and K consumed were found to be higher because the IPS and IKS of soil were high. This might be due to higher available P_2O_5 and K_2O in soil. Nutrient consumed per Mg of grain provides guideline to calculate the NPK requirement to achieve a certain target yield. The total nutrient NPK requirements for target yield of 3.5 Mg/ha was calculated to be 82, 38 and 92 kg NPK/ha.

Indigenous nutrient supplying capacity of soil

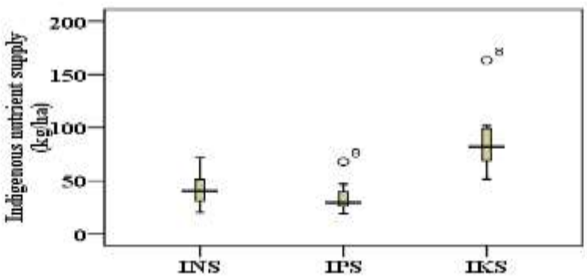

Fig. 1: Indigenous nutrient (NPK) supplying capacity of soil (kg/ha) in *Bari* land of Khasyoli VDC of Palpa district, 2011

The wide variation in INS (20-71 kg/ha), IPS (19-68 kg/ha), and IKS (51-164 kg/ha) among eight farmers' field could be due to variation in topography of *Bari* land, soil pH, available nutrients, fertilizer dose, and crop management practices followed by farmers. Nutrient supplying capacity of soil depends on the indigenous soil properties, mostly the chemical properties, nutrient availability and soil fertility. As the indigenous soil properties varied largely among the farmers' field, the indigenous nutrient supply for N, P, and K also varied (Fig. 1). Witt *et al.* (2007) found that field-to-field variability of soil properties in relation to parent material affected the soil nutrient supplying capacity and relevant crop growth factors. Recovery efficiency of nitrogen, phosphorus, and potassium fertilizer in maize in FFP and ample NPK plots is shown in Table 4.

Table 4: Recovery efficiency of nitrogen, phosphorus, and potassium fertilizer in maize in FFP and ample NPK plots, 2011

Fertilizer	Recovery efficiency in FFP plot		Recovery efficiency in ample NPK plot	
	kg NPK/ kg NPK	Percentage	kg NPK/ kg NPK	Percentage
Nitrogen	0.06	6	0.28	28
Phosphorus	-0.5	-50	0.2	20
Potassium	-9	-90	0.8	80

Fertilizer nutrient requirement

Considering the average indigenous NPK supplying capacity of soil the nutrient NPK requirement from external source (fertilizer) was calculated to be 143, 18, and 3 kg/ha. The fertilizer nitrogen requirement was recorded to be higher than recommended by NARC and MOAC. This is because the INS of soil was low and farmers should apply higher amount of nitrogen fertilizer to meet the crop nitrogen requirement for target yield. The phosphorus and potassium fertilizer requirement was found to be lower than recommended by NARC and MOAC because the IPS and IKS of soil was higher and farmers can apply lower amount of P and K fertilizer to meet the crop P and K requirement for target yield.

This average NPK requirement doesn't work well for all the eight farmers as the indigenous NPK supply varies among farmers' field. Hence, considering the variation in indigenous NPK supply of eight farmers, the NPK requirement from the external source (fertilizer) was calculated to be ranging from 40-222, 0-90, and 0-50 kg/ha, respectively. There was large variation in indigenous NPK supply of eight farmers' field. So, the nutrient NPK requirement also varies. The negative value for fertilizer P and K requirement, in *Bari* land of few farmers, indicates that the IPS and IKS of soil was higher than total P and K requirement of maize crop and there is no need to apply P and K fertilizer. It was already discussed that the INS capacity of soil of farmers' field varies from one another. Considering the INS of eight farmers' field, it is difficult to recommend fertilizer for all the farmers of Khasyoli VDC. For more valid fertilizer dose recommendation more number of farmers should be considered and categorized into 2-3 recommendation domains according to the similar indigenous nutrient supply (Fig. 2).

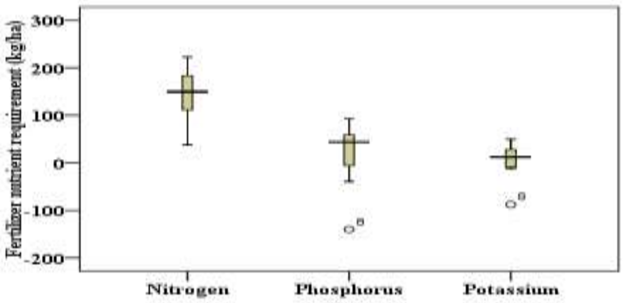

Fig 2: Fertilizer nutrient (NPK) requirement for maize in Khasyoli VDC of Palpa district

Conclusions

Soil of Khasyoli VDC was poor in available N and indigenous N supply, but rich in available P_2O_5 and K_2O, and indigenous P and K supply. Moreover, farmers were applying lower dose of N than recommended and practiced poor nutrient and crop management. This resulted in lower N use efficiency and ultimately the lower grain yield in farmers' fertilization practice. Spatial variation in INS of soil exists in Khasyoli VDC, mainly because of difference in indigenous soil properties and nutrient and crop management practices. So, quantification of INS of soil for major nutrients NPK is a pre-requisite to increase nutrient use efficiency and yield of maize based cropping system. In order to maintain soil productivity and reach the same target yield of maize, farmers need to significantly increase dose of N fertilizer, while they may apply no or lower dose of P_2O_5 and K_2O fertilizer. Considering the INS of eight farmers' field and one season, the initial recommendation of fertilizer dose for Khasyoli VDC varies from 40 to 222 kg N, 0 to 93 kg P_2O_5,and 0 to 50 kg K_2O per ha.

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