

## Fertilizer recommendations based on targeted yield concept involving integrated nutrient management for potato (*Solanum tuberosum*) in tarai belt of Uttarakhand

DIBYENDU CHATTERJEE<sup>1</sup>, AJAYA SRIVASTAVA<sup>2</sup> and R K SINGH<sup>3</sup>

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, 263 145

Received: 17 December 2009; Revised accepted: 20 September 2010

### ABSTRACT

Soil-test crop response of potato (*Solanum tuberosum* L.) was studied in Mollisol during winter (*rabi*) season, 2006–07. Four levels of fertilizer N, P, K and 3 levels of farmyard manure were randomly distributed in 24 plots and 3 fertility strips with a total of 72 plots. Soil and plant analysis data were exploited to formulate fertilizer adjustment equations for each strip with and without farmyard manure at varying yield targets at different fertility levels. Co-efficient of determination ( $R^2$ ) was found significant (0.614\*\*) between yield and soil test values. Based on the experiment, the nutrient requirement for producing 100 kg of potato tuber was 0.33 kg of N, 0.05 kg of P and 0.40 kg of K. The per cent contribution from soil was 20.01, 8.02 and 19.84; from applied farmyard manure 12.82, 1.32 and 14.49 and from fertilizer 15.41, 5.43 and 26.21 for N, P and K, respectively. Verification trial of this experiment was done in the next season, ie during winter (*rabi*), 2007–08. The variation in yield obtained from the targeted yield ranged from +9.77 to –9.76%. The farmers' practice of fertilizer application and control were least efficient in producing tuber yield of potato. Both the highest cost : benefit and response ratio was found with farmyard manure 10 tonnes/ha + yield target 2000 kg/ha.

**Key words:** Fertilizer adjustment equation, Potato, Soil test crop response, Yield target

Potato (*Solanum tuberosum* L.) is the world's fourth important food crop after wheat, rice and maize owing to its great yield potential and high nutritive value and accounts for nearly half of the world's annual output of all root and tuber crops. It is a heavy feeder of plant nutrients having high requirement of nitrogen, phosphorus, potassium and other nutrients. Singh and Kushwah (2006) suggested the combined use of inorganic and organic sources of nutrients in potato. But presently, there is no information regarding soil test-based crop response for achievement of different yield targets of 'Kufri Jyoti' potato which is the major cultivated variety of this region. The theory of formulating optimum fertilizer recommendations for targeted yield was first given by Troug (1960), which was further modified by Ramamoorthy *et al.* (1967). The data obtained from the Soil Test Crop Response field experiment provides a range in soil test values, nutrient uptake and yield levels which enable

in calculating the 3 basic parameters as nutrient requirement, per cent contribution of available nutrient from soils ( $C_S$ ) and the per cent contribution from the applied fertilizer ( $C_F$ ) or organic manures ( $C_{FYM}$ ). In the field experiment, the yield variations due to management practices and soil factors other than the nutrients are avoided by creating the desired fertility gradient artificially by growing 'Shweta' maize (*Zea mays* L.), followed by test crop, ie potato. Keeping above factors in view, an experiment was conducted with 'Kufri Jyoti' potato.

### MATERIALS AND METHODS

A field experiment was conducted at Crop Research Centre of the University, Pantnagar, Uttarakhand during winter (*rabi*) 2006–07. Before conducting the test crop experiment, fertility gradient stabilizing experiment was conducted by sowing 'Shweta' maize as an exhaust crop during *kharif* 2006 to minimize the interference of other soil and management factors affecting crop yield. Experimental site was divided into 3 equal strips (38.5 m × 9.5 m) and 3 levels of nutrients, viz 0–0–0, 120–60–40, 240–120–80 kg/ha N,  $P_2O_5$  and  $K_2O$ , respectively were applied. Crop was harvested after 90 days.

At the second phase, a test crop 'Kufri Jyoti' potato was grown during winter (*rabi*) 2006–07 on the site of fertility

Based on complete information of MSc thesis of the first author submitted to GBPUAT, Pantnagar during 2007

<sup>1</sup>M Sc student (e mail: dibyenducha@gmail.com), <sup>2</sup>Associate Professor/SRO (e mail: ajayasoilari@gmail.com), Department of Soil Science;

<sup>3</sup>Research Associate (e mail: rksingh.icar@gmail.com) NAIP-ICAR, KAB-II, Pusa Campus, New Delhi 110 012

gradient experiment. Each strip (made in the fertility gradient stabilizing experiment in the previous season) was divided into 24 plots (21 treatments + 3 controls) resulting in 72 (24×3) plots. Three blocks (A, B, C) comprising of 8 treatments were made within a strip randomized with farmyard manure levels. These treatments comprised various selected combinations levels of nitrogen (N<sub>0</sub>, N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub>, ie 0, 100, 150, 200 kg N/ha), phosphorus (P<sub>0</sub>, P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, ie 0, 50, 100, 150 kg P<sub>2</sub>O<sub>5</sub>/ha), potassium (K<sub>0</sub>, K<sub>1</sub>, K<sub>2</sub>, K<sub>3</sub>, ie 0, 50, 100, 150 kg K<sub>2</sub>O/ha) and farmyard manure (F<sub>0</sub>, F<sub>1</sub>, F<sub>2</sub>, ie 0, 10, 20 tonnes farmyard manure/ha) were randomized in each of the 3 strips.

To validate the recommendations of fertilizer and farmyard manure for targeted yields for potato using adjustment equations, a verification trial was conducted during winter (*rabi*), 2007–08. Eight treatments with 3 replications were taken, viz control (T<sub>1</sub>), farmers' practice (T<sub>2</sub>), general recommendations (T<sub>3</sub>), farmyard manure 10 tonnes/ha (T<sub>4</sub>), yield target 2000 kg/ha (T<sub>5</sub>), yield target 2500 kg/ha (T<sub>6</sub>), farmyard manure 10 tonnes/ha + yield target (T<sub>7</sub>), farmyard manure 10 tonnes/ha + yield target (T<sub>8</sub>). Standard agronomic practices were followed for growing both maize and potato.

Soil samples at 0–0.15 m depth were collected from each plot before and after sowing of test crop and analyzed for per cent organic carbon, available nitrogen by alkaline-KMnO<sub>4</sub> method, available phosphorus by 0.5 M NaHCO<sub>3</sub> (pH 8.5) extraction method followed by colour development by ascorbic acid method, available potassium in soil extracted by 1 N neutral NH<sub>4</sub>OAc. Composite plant samples were collected from each plot at physiological maturity stage and digested before chemical analysis by using diacid mixture (concentrated HNO<sub>3</sub> and HClO<sub>4</sub> in the ratio of 9:4 by volume) for phosphorus and potassium while concentrated H<sub>2</sub>SO<sub>4</sub> was used for nitrogen. These were analyzed for total nitrogen content by modified microkjeldahl method, total phosphorus content by following vanado-molybdate phosphoric acid yellow colour method and total potassium content by using flame photometer directly.

Total uptake of each nutrient was calculated by the following formula:

Uptake (kg/ha) = per cent nutrient (kg/kg) × dry matter yield (kg/ha).

Total uptake of nutrient (kg/ha) = uptake by tuber (kg/ha) + uptake by haulm (kg/ha).

By using tuber yield, nutrient uptake data, fertilizer doses and soil test values, basic data were calculated as follows:

$$\text{Nutrient requirement (NR)} = \frac{\text{Total nutrient uptake (kg/ha)}}{\text{Tuber yield (kg/ha)}}$$

The values were reported as kg of N, P and K required to produce 100 kg of tuber.

$$\text{Per cent contribution of nutrient from soil (C}_S) = \frac{\text{Total uptake in control plot} \times 100}{\text{STV of that nutrient in control plot}}$$

$$\text{Per cent contribution of concerned nutrient from fertilizer (C}_F) = \frac{\left( \text{Total uptake in treated plots} \right) - \left( \text{STV} \times \frac{\text{C}_S}{100} \right)}{\text{Amount of nutrient added as fertilizer}} \times 100$$

$$\text{Per cent contribution of nutrient from FYM (C}_{\text{FYM}}) = \frac{\left( \text{Uptake in FYM plot} \right) - \left( \text{STV} \times \frac{\text{C}_S}{100} \right)}{\text{Nutrient added as FYM}} \times 100$$

Equations for fertilizer requirement of nitrogen, phosphorus and potassium for targeted yield were worked out as follows:

Fertilizer requirement equations for nutrients through chemical fertilizer only,

$$\text{FD} = \frac{\text{NR}}{\text{C}_F} \times 100 \text{ T} - \frac{\text{C}_S}{\text{C}_F} \times \text{STV}$$

Fertilizer requirement equations for nutrients through conjoint use of chemical fertilizer and farmyard manure,

$$\text{FD} = \frac{\text{NR}}{\text{C}_F} \times 100 \text{ T} - \frac{\text{C}_S}{\text{C}_F} \times \text{STV} - \frac{\text{C}_{\text{FYM}}}{\text{C}_F} \times \text{M}$$

where T, Targeted yield (kg/ha); FD, fertilizer dose (kg/ha); STV, soil test values for available N, P, K (kg/ha); M, concerned nutrient content in organic matter (kg/ha).

Multiple regression approach is used to calculate the dose of nutrient(s) required to obtain the maximum yield of crops under given set of experimental conditions. It can further be used to calculate the economic dose of fertilizer nutrients by incorporating a constant factor, i e per unit cost of produce divided by per unit cost of input (fertilizer) in the original equation. In this approach, yield is regressed with soil nutrients, fertilizer nutrients, their quadratic terms and the interaction term of soil and fertilizer nutrients as given below:  $Y = A \pm b_1 \text{SN} \pm b_2 \text{SN}^2 \pm b_3 \text{SP} \pm b_4 + \text{SP}^2 \pm b_5 \text{SK} \pm b_6 \text{SK}^2 \pm b_7 \text{FN} \pm b_8 \text{FN}^2 \pm b_9 \text{FP} \pm b_{10} \text{FP}^2 \pm b_{11} \text{FK} \pm b_{12} \text{FK}^2 \pm b_{13} \text{FNSN} \pm b_{14} \text{FPSP} \pm b_{15} \text{FKSK}$

where Y = Crop yield (kg/ha); A = intercept (kg/ha); b<sub>1</sub> = regression coefficients (kg/ha); SN, SP, SK = available soil nitrogen, phosphorus and potassium (kg/ha) respectively; FN, FP, FK = fertilizer nitrogen, phosphorus and potassium (kg/ha), respectively.

## RESULTS AND DISCUSSION

### *Fertility gradient establishment experimentation*

Strip-wise range and average of soil test values for nitrogen, phosphorus and potassium are given in Table 1. In principle strip III should be richest in fertility status, followed by strip II and further followed by strip I with poorest fertility. Hence, highest amount of fertilizer nitrogen, phosphorus and potash was applied in strip III, followed by less of those in strip II, while no fertilizer was applied in strip I. The nitrogen

Table 1 Range and mean of the soil test values under different strips

Particulars	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
Organic carbon (%)	0.49–1.14	0.76	0.60–0.95	0.79	0.72–1.02	0.87
Alkaline $\text{KMnO}_4\text{-N}$ (kg/ha)	87.8–138.0	110.5	87.81–137.98	112.41	112.89–137.98	124.48
Olsen's-P(kg/ha)	39.7–68.3	55.1	49.7–79.7	66.1	65.3–97.5	76.9
$\text{NH}_4\text{OAc-K}$ (kg/ha)	131.0–194.9	161.4	140.0–198.24	166.92	141.12–221.76	188.89

extracted as alkaline  $\text{KMnO}_4\text{-N}$  as well as soil organic carbon content were found in the order, strip III > strip II > strip I (Table 1). The phosphorus extracted by Olsen's method indicated the highest value of Olsen's-P in strip III, followed by strip II and it was the lowest in strip I. Similar trend was also noted for neutral normal  $\text{NH}_4\text{OAc-K}$  in different strips (Table 1). Analysis of variance was carried out using the soil nutrients, and are given in Table 2.

Table 2 Significance, R square, CV (%) and mean of soil test values of whole plots

Dependent variable	Prob.> F	R <sup>2</sup>	CV	Mean
Alkaline $\text{KMnO}_4\text{-N}$ (kg/ha)	0.0008**	0.187	11.43	115.68
Olsen's-P (kg/ha)	<0.0001**	0.549	12.23	65.97
Ammonium acetate-K (kg/ha)	<0.0001**	0.347	9.93	172.49

#### Test crop experimentation

Range and mean of potato yield and nutrient uptake under different strips are given in Table 3. Maximum yield of tuber was obtained in strip III, followed by strip II and it was lowest in strip I with very large difference with strip I, i.e. low fertility gradient strip, but the difference was less between strip II and strip III, i.e. between medium and high fertility gradient strips. Haulm yield showed reverse trend particularly in the treated plots. Getting more tuber yield with increasing fertilizer dose was supported by Sarker *et al.* (2007). The increase in tuber yield with 150% recommended dose of fertilizer (RDF) over 100% was 2.8%. Similarly, strip-wise average nutrient uptake was in the order of strip III > strip II > strip I. Singh *et al.* (1996) showed that the uptake of N and K was increased with application of higher dose of farmyard manure and it significantly increased N and K contents of tubers.

Fertilizer N, P and K for targeted yield of potato were calculated by using the equations

$$\text{FN} = 2.10 \text{ T} - 0.95 \text{ SN} - 0.53 \text{ FYM-N}$$

$$\text{FP} = 0.99 \text{ T} - 1.48 \text{ SP} - 0.24 \text{ FYM-P}$$

$$\text{FK} = 1.51 \text{ T} - 0.76 \text{ SK} - 0.55 \text{ FYM-K}$$

Where, FN, Fertilizer nitrogen dose (kg/ha); FP, fertilizer phosphorus dose (kg/ha); FK, fertilizer potassium dose (kg/ha); T = yield target (kg/ha), SN = alkaline  $\text{KMnO}_4\text{-N}$  (kg/ha), SP = Olsen's-P (kg/ha), SK = ammonium acetate-K (kg/ha), FYM-N = amount of N applied through organic manure (kg/ha), FYM-P = amount of P applied through organic manure (kg/ha) and FYM-K = amount of N applied through organic manure (kg/ha). Basic data to calculate nutrient dose for targeted yield of potato and total uptake of nitrogen, phosphorus and potassium in treated and control plots are presented in Table 4. The nutrient requirement for production of 100 kg of potato tuber was 0.33 kg of N, 0.05 kg of P and 0.40 kg of K. Per cent contribution of N, P and K from soil was 20.01, 8.02 and 19.84, respectively. Contribution from fertilizer as percentage of its nutrient content was 15.41, 5.43 and 26.21 N, P and K, respectively. These were same for both with farmyard manure and without farmyard manure cases. Per cent contribution of nutrient from applied farmyard manure for nitrogen, phosphorus and potassium was 12.82, 1.32 and 14.49, respectively in case of organic manure application (with farmyard manure). Singh *et al.* (1996) reported that the uptake of N and K was increased with application of higher dose of farmyard manure and it significantly increased N and K contents of tubers. Ahmed and Reddy (2004) reported that in case of '87A-298' sugarcane based on fertility gradient approach, the cane yield was positively correlated with N, P and K uptake. Fertilizer requirement for nitrogen, phosphorus and potassium at different soil test values for the production

Table 3 Range and mean of potato yield and nutrient uptake under different strips

Particulars	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
Tuber yield (kg/ha)	529.9 – 1664.4	1 179.0	760.5 – 1 787.0	1 312.6	642.1 – 1712.2	1 338.0
Haulm yield (kg/ha)	72.3 – 407.8	2 320.0	73.6 – 405.0	183.3	88.3 – 256.6	161.0
Nitrogen uptake (kg/ha)	15.2 – 69.7	40.5	18.0 – 59.6	42.2	22.8 – 67.8	43.2
Phosphorus uptake (kg/ha)	3.3 – 9.2	6.63	3.7 – 11.1	6.79	4.8 – 9.1	6.81
Potassium uptake (kg/ha)	27.7 – 73.1	47.3	24.7 – 77.2	50.4	31.5 – 74.1	52.4

Table 4 Basic data for calculating fertilizer dose with farmyard manure for targeted yield of 'Kufri Jyoti' potato

Particulars	With farmyard manure			Without farmyard manure		
	(N)	(P)	(K)	(N)	(P)	(K)
Nutrient required (kg) to produce 100 kg of tuber (NR)	0.33	0.05	0.40	0.33	0.05	0.40
Per cent contribution of available nutrient from soil ( $C_s$ )*or soil efficiency	20.01	8.02	19.84	20.01	8.02	19.84
Per cent contribution from applied fertilizer nutrient ( $C_f$ )* or fertilizer efficiency	15.41	5.43	26.21	15.41	5.43	26.21
Per cent contribution of nutrient from applied farmyard manure ( $C_{FYM}$ )* or organic efficiency (%)	12.82	1.32	14.49			

\*Soil test values (0–0.15 m depth); alkaline  $KMnO_4$ -N (kg/ha), Olsen's-P (kg/ha) and  $NH_4OAc$ -K (kg/ha)

of various targeted yield was calculated from the basic data with 10 tonnes farmyard manure (Fig 1) and without farmyard manure (Fig 2).

Relationship between tuber yield as dependent variable and the soil test values, fertilizer doses, farmyard manure doses, interactions between soil test values, fertilizer doses and among fertilizer nutrients as independent variables was established through a multiple regression equation of quadratic model.

$$Y = 28.853 - 0.343 FN + 0.524 FP + 0.513 FK - 0.474 SN + 0.523 SP + 0.435 SK + 0.0007531 FN^2 - 0.000193 FP^2 - 0.002293 FK^2 + 0.003861 FNSN - 0.007046 FPSP - 0.0005357 FKSK \quad (R^2 = 0.614^{**})$$

From  $R^2$  value, it can be observed that variation up to 61.4% in potato tuber yield can be explained by the variation in soil test values and fertilizer doses. Generally, at a given soil test value, the yield will increase up to a limit with increasing dose of fertilizer and beyond which the yield will not increase but decrease, following the 'Law of Diminishing

Return.' In a quadratic type response curve, this happens only when the linear term is positive for any fertilizer nutrient and quadratic and interaction terms are negative (+ --). The response type (+ --) characterizes at a given soil test value, the yield increases up to a limit with increasing doses of fertilizer but above which, there will be no increase but decrease in yield. These response types (+ --) for the nutrients phosphorus and potassium followed Law of Diminishing return. While the response type (+ +) observed for nitrogen, characterizes that there is positive and increasing response to applied fertilizer and negative correlation between soil and fertilizer nutrients.

#### Verification trial

The verification trials are important since the calibration of results obtained on research farm are required to be tested for their validity. The objectives of these trials are to test the validity of the results obtained from the main experiment before recommending these for adoption by extension

Table 5 Economics of verification trial of 'Kufri Bahar' potato

Treatment	Fertilizer dose N-P-K-FYM (kg/ha)	Actual mean yield (kg/ha)	Additional yield (kg/ha)	Value of additional yield (Rs)	Cost of fertilizer (Rs)	Net benefit (Rs)	B/C ratio	Response ratio	Yield deviation (%)
T <sub>1</sub> Control	0-0-0	15 472	0	0	0.00	0.0			
T <sub>2</sub> farmers' practice	70-64-32-5	16 000							
T <sub>3</sub> general recommendation	150-100-100-10	20 472	4 472	53 666	16 666	37 000	2.22	12.78	
T <sub>4</sub> FYM 10 tonnes/ha	0-0-0-10	16 083	83	1 000	500	500	1.00		
T <sub>5</sub> yield target 2 000 kg/ha	162.2-94.5-150.1-0	21 166	5 166	62 000	16 395	45 605	2.78	12.70	5.51
T <sub>6</sub> yield target 2 500 kg/ha	267.6-143.9-225.5-0	22 777	6 777	81 333	25 410	55 922	2.20	10.64	-9.76
T <sub>7</sub> FYM 10 tonnes/ha + yield target 2 000 kg/ha	162.2-94.5-150.1-10	22 166	6 166	74 000	16 895	57 105	3.38	15.16	9.77
T <sub>8</sub> FYM 10 tonnes/ha + yield target 2 500 kg/ha	267.6-143.9-225.5-10	24 138	8 138	97 666	25 910	71 755	2.77	12.78	-3.57
SEm = 0.286									
CD (P=0.01) 1.20									
CV= 2.09%									

Rate N 10.5, P<sub>2</sub>O<sub>5</sub> 18.5 and K<sub>2</sub>O 7.08 ₹/kg; Potato tuber ₹ 12/kg; FYM, farmyard manure

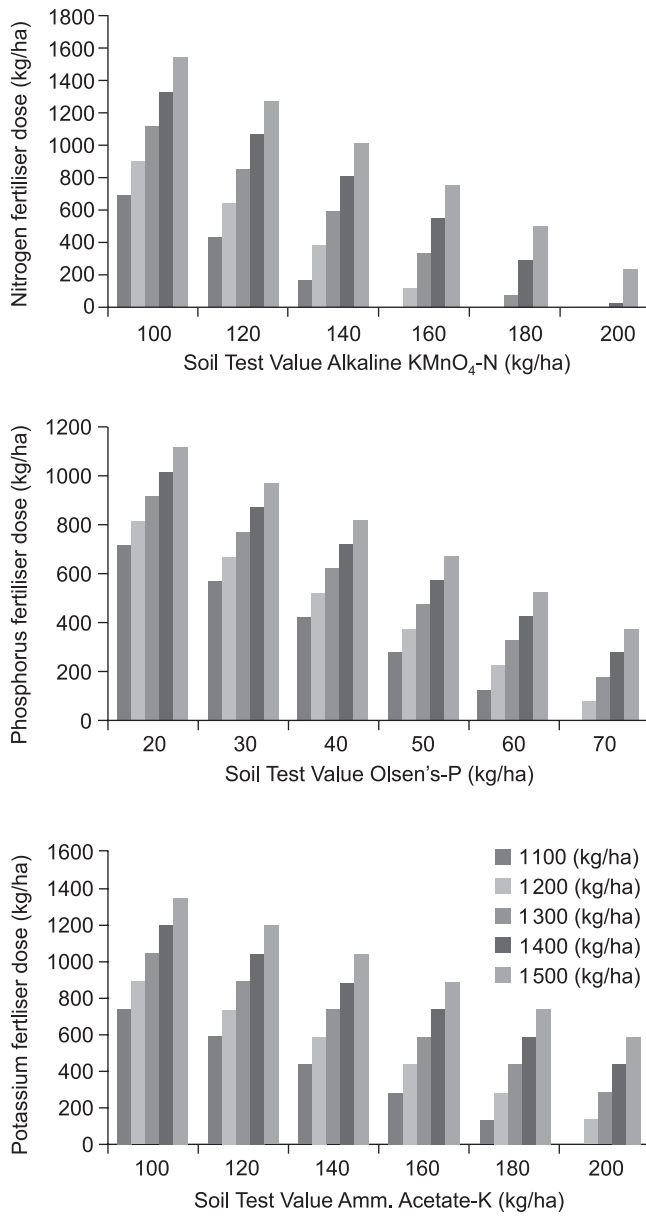


Fig 1 Fertilizer dose (kg/ha) for tuber yield of potato (kg/ha) with 10 tonnes farmyard manure

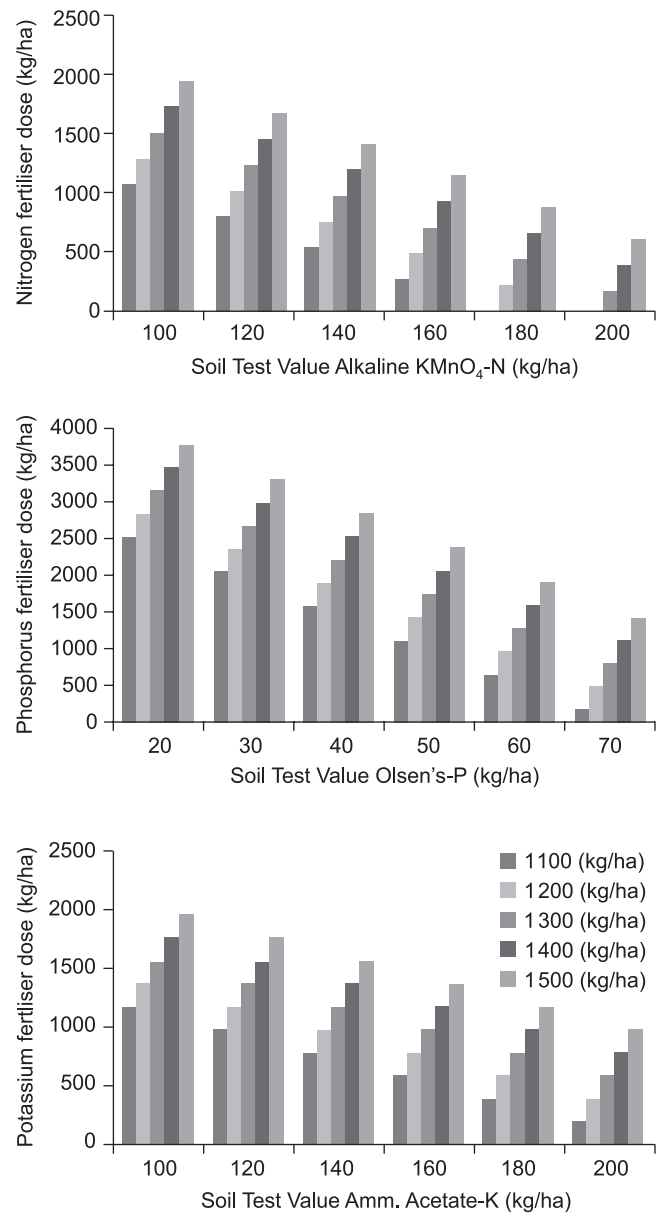


Fig 2 Fertilizer dose (kg/ha) for tuber yield of potato (kg/ha) without farmyard manure

agencies and to show the farmers, the greater profitability of the soil test-based fertilizer recommendation than general recommended dose. The results obtained in verification trial are presented in Table 5. Among the treatments, targets of 2 000 kg/ha (T<sub>5</sub>), 2 500 kg/ha (T<sub>6</sub>), 10 tonnes farmyard manure/ha + yield target 2 000 kg/ha (T<sub>7</sub>), 10 tonnes farmyard manure/ha + yield target 2 500 kg/ha (T<sub>8</sub>) and general recommendation (T<sub>3</sub>) gave significantly higher yield over farmers' practice. The variation in yield obtained from the targeted yield ranged from -9.76 to +9.77%. The farmers' practice of fertilizer application and control were least efficient in producing tuber yield of potato. A net benefit of

target yield was highest with 10 tonnes farmyard manure/ha + yield target 2 500 kg/ha (T<sub>8</sub>). Fertilizer application based on targeted yield approach was found to be superior to general recommended dose. Organic manure alone gave B : C ratio unity, indicating equal amount of cost of organics and net benefit. Highest benefit cost and response ratio was found with farmyard manure 10 tonnes/ha+ yield target 2 000 kg/ha (T<sub>7</sub>). Sasani *et al.* (2003) reported that remunerative higher yield of 'Kufri Badsah' potato can be obtained under north Gujarat condition by the application of 25% extra dose of NPK fertilizers than recommended dose of inorganic fertilizer along with 25

tonnes farmyard manure/ha. Saxena *et al.* (2008) observed higher benefit:cost ratio through targeted yield approach in comparison to general recommended dose (GRD) in onion ('Nasik Red') of Pantnagar in Uttarakhand. Milapchand *et al.* (2006) also found similar results with mustard and rapeseed in Punjab.

These findings can successfully be used in the larger parts of *tarai* region of Uttarakhand as effective guide for efficient fertilizer management by reducing cost of cultivation, increasing fertilizer-use efficiency and keeping environment pollution free, maintaining soil quality and soil health with judicious use of chemical fertilizers. Therefore, soil test-based fertilizer recommendation may be a useful tool for balanced fertilization of nutrients.

#### REFERENCES

- Ahmed S R and Reddy P V K. 2004. Influence of organic manure (farmyard manure) in prescription of inorganic fertilizers for different yield targets of sugarcane (*Saccharum officinarum* L.) based on soil test crop response correlation. *Cooperative Sugar* **36**(1): 29–36.
- Milap-Chand, Benbi D K and Azaad A S. 2006. Fertilizer recommendation based on soil tests for yield targets of mustard and rapeseed and their validations under farmers' field condition in Punjab. *Journal of the Indian Society of Soil Science* **54**: 316–21.
- Ramamoorthy B, Narasimham R L and Dinesh R S. 1967. Fertilizer application for specific yield targets of Sonora 64. *Indian Farming* **17** (5): 43–4.
- Sarker B, Mondal S S, Nayek S S, Saha M and Biawas S. 2007. Integrated nutrient management for the productivity and quality improvement of potato under irrigated condition. *Potato Journal* **34** (1–2): 99–100.
- Sasani G V, Patel C K, Patel R N and Patel N H. 2003. Effect of levels of inorganic fertilizer with and without organic manure on yield of potato in North Gujarat. *Journal of the Indian Potato Association* **30** (1–2): 77–8.
- Saxena A K, Singh S, Srivastava A and Gautam P. 2008. Yield target approach under integrated nutrient management for assessing fertilizer requirements of onion in Mollisols of Uttarakhand. *Indian Journal of Horticulture* **65**(3): 302–6.
- Singh J P, Marwaha R S and Grewal J S. 1996. Effect of sources and levels of potassium in potato yield, quality and storage behaviour. *Journal of the Indian Potato Association* **23** (3–4): 153–6.
- Singh S P and Kushwah V S. 2006. Effect of integrated use of organic and inorganic sources of nutrients on potato (*Solanum tuberosum*) production. *Indian Journal of Agronomy* **51**(3): 236–8.
- Singh S P, Singh V and Lakhan R. 1996. Effect of phosphorus and farmyard manure application on yield, content and uptake of nitrogen, phosphorus and sulphur by potato. (*Solanum tuberosum* L.). *Indian Journal of Agronomy* **41**(4): 630–2.
- Truog E. 1960. Fifty years of soil testing. *Transactions of Seventh International Congress of Soil Science*, Vol. 3, Commission IV, Paper No. 7: 46–53.