Integrated nutrient management and formulation of fertilizer prescription equation for recommendation of fertilizers for potato on alluvial soils of eastern India

S.P. Mazumdar*, A.R. Saha, B. Majumdar, M. Kumar, N.M. Alam, P. Dey, R. Saha, S. Sasmal and R. Bhattacharya

Crop Production Division, ICAR - Central Research Institute for Jute and Allied Fibres, Barrackpore - 700 120, India

*Corresponding Author Email : sonalimazumdar110@gmail.com

Paper received: 25.03.2019

Revised received: 08.06.2019

Accepted: 21.09.2019

Abstract

Aim : To develop economically viable integrated fertilizer prescription equation for recommendation of fertilizers in potato on alluvial soils of Eastern India.

Methodology : Soil test crop response (STCR) experiments on potato were conducted in alluvial soils of Eastern India during 2016-17 to assess the relationship between yield and availability of plant nutrients for developing fertilizer prescriptions of desired yield targets. The decision on optimum fertilizer doses for varying yield targets were made on the basis of crop nutrient requirement per quintal of potato production, soil efficiency, fertilizer efficiency, and FYM efficiency computed from field experimental data. The optimum fertilizer doses for different yield targets were validated in farmers' field for economic and environmental benefits as compared to general recommended doses of fertilizers and farmers' practice.

Results : Targeted yield equation for potato for alluvial soil of Eastern India was developed based on soil test values, nutrient requirement and contribution of NPK from soil and fertilizer sources as well as FYM. The prescription based fertilizer application along with FYM increased tuber yield of potato in farmers' field. Validity of the yield target for 22 and 24 t ha⁻¹ was tested in farmer's fields and variation in potato yield obtained from targeted yield was 7.6% to 9.8%.

Interpretation : Fertilizer prescription equations and ready reckoner developed for potato will be useful in alluvial soils of Eastern India for large scale recommendations and in regions with similar soil and agro-climatic conditions. By following ready reckoner, a farmer can save 61 kg N, 55 kg P₂O₅ and 44 kg K₂O ha⁻¹ over general recommended dose, approximately equal to Rs. 4800/- per hectare.

Key words: Alluvial soil, Fertilizer prescription equation, Nutrient requirement, Potato, Targeted yield

How to cite : Mazumdar, S.P., A.R. Saha, B. Majumdar, M. Kumar, N.M. Alam, P. Dey, R. Saha, S. Sasmal and R. Bhattacharya : Integrated nutrient management and formulation of fertilizer prescription equation for recommendation of fertilizers for potato on alluvial soils of eastern India. *J. Environ. Biol.*, **41**, 92-100 (2020).

Introduction

Potato (*Solanum tuberosum* L.) is a major global vegetable crop which belongs to family *Solanaceae*. In terms of human consumption, potato is the fourth most important food crop after wheat, rice and maize (Pandey *et al.*, 2005; Reshi *et al.*, 2013) as it influences the livelihood of four billion people. Potato is said to have originated, ten thousand years ago in South America then came to Europe of the cultural renaissance, and till date it occupies first position in vegetable cultivation all over the world. It is not only the preferred vegetable in European Union but also in developing countries with an annual global production of about 382 million tonnes (FAOSTAT, 2014). Potato is one of the important economically staple food crops in both developed and developing countries. China is the world's largest potato producer, followed by Russia and India. Production of potato in India is about 43.39 million tonnes which is largely in Himachal Pradesh, Uttar Pradesh and West Bengal and it occupies 2.024 million ha of land, accounting for 10.6% of global area and 12.2% of global production. It is a short-duration and rapid bulking crop. It produces maximum yield per unit area and per unit of time than cereals and pulses. Potato consume huge quantity of plant nutrients (Fernandes *et al.*, 2011), and in modern agriculture use of inorganic fertilizers is an important component for higher production of field crops. However, imbalanced use of chemical fertilizers and limited organic use is posing a serious threat to the environment and subsequent deterioration of soil quality. Therefore, there is a need to develop new technology which will be helpful in maintaining soil fertility, simultaneously with improved crop production and increased nutrient use efficiencies resulting in overall sustainability of the system.

Concept of targeted yield based fertilizer application for crops was first given by Truog (1960), and later modified by Ramamoorthy *et al.* (1967). Targeted yield based fertilizer application, depending on the deficiency of nutrients in soil results in higher response ratio and benefit cost ratio as nutrient are applied in proportion to the magnitude of deficiency of a particular nutrient (Rao and Srivastava, 2000). Based on this approach, site specific fertilizer application for similar soil class and environment may be recommended, based on soil fertility status, economy of farmers and level of yield target (Ahmed *et al.*, 2002). Optimum quantity and field specific nutrient requirement of crops were recommended on the basis of nutrient contribution from soil and prediction model of yield response as a function of nutrient interaction (Dobermann and White, 1998; Witt *et al.*, 1999). Fertilizer prescription equations have been developed for crops like rice (Bera *et al.*, 2006) and maize (Brajendra *et al.*, 2012). Similarly, integrated fertilizer prescription equations for recommendation of fertilizer in jute-rice-garden-pea on alluvial soils of Eastern India were formulated by Singh *et al.* (2015). The need to apply balanced fertilizer according to crop requirement and soil available nutrients has been recognised as a better approach than practice of general recommended dose of fertilizer in onion (Saxena *et al.*, 2008). Fertilizer adjustment equations of optimum fertilizer doses at varying soil test values for attaining

higher yield target of groundnut (Pradhan *et al.*, 2007), sorghum (Solaippan *et al.*, 2008), mustard (Verma *et al.*, 2017) etc., have been developed. However, there is lack of information regarding fertilizer prescription equation for potato in alluvial soils.

For judicious application of fertilizers, there is a need for fertilizer recommendation on the basis of nutrient requirement of the crop, inherent fertility status of the soil and also on integrated nutrient supply system. Therefore, a new approach of location specific fertilizer application on the basis of soil test against the existing practice of general fertilizer recommendation is promoted among the farming community to overcome the current mismatch of fertilizer rates and crop nutrient demand. Fertilizer application by this method is meaningful and eco-friendly. Fertilizer savings, mean yield, net benefit and benefit-cost ratio is higher where fertilizer was applied on the basis of fertilizer prescription equations as compared to recommended dose or farmers' practice (Bhaduri and Gautam, 2013; Mazumdar *et al.*, 2018; Sharma *et al.*, 2015). Therefore, the present investigation was undertaken with the objective to develop integrated fertilizer prescription equation for potato in alluvial soils of Eastern India to accomplish judicious application of fertilizers for maximum production of potato. In addition, developed fertilizer prescription equation was validated in farmers' fields.

Materials and Methods

Study site: A trial was undertaken during year 2016-17 with potato as a test crop at the experimental farm of ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata, India. The climate of the site is sub-humid to humid tropical in nature. Mean annual rainfall of the area is 1066 mm. Soil of the experimental site was of lower Gangetic alluvium (Typic Ustochrept). The soil was well drained and moderately deep. Texture of the soil was sandy clay loam with pH 7.1 and non-saline in electrical conductivity (0.32 dS m^{-1}). The initial oxidizable soil organic carbon was recorded as 0.73% whereas soil available alkaline potassium permanganate nitrogen ($\text{KMnO}_4\text{-N}$), Olsen phosphorus (P) and ammonium acetate extractable potassium ($\text{NH}_4\text{OAc-K}$) levels were estimated as 273, 88.5 and 196 kg ha^{-1} , respectively. Soil of the experimental site was thus low in available N, high in available P and medium in available K. The verification trial was conducted at farmer's field for two consecutive years in the same agro-ecological region (Bhabanipur village of Nadia, West Bengal, India) during winter season.

Fertility gradient experiment: To undertake the main experiment, creation of fertility gradient was necessary as experiment was to undertake soils of different fertility status. Hence, fertility gradient was created artificially to obtain different fertility status in same area. For creating fertility gradient, the experimental field was divided in three long strips (L_0 , L_1 and L_2), each strip long 63 m and 8 m wide. The strips were provided with different doses of inorganic fertilizer (N, P and K). Variation in soil fertility was created by applying $100\text{--}80\text{--}100 \text{ kg ha}^{-1}$ of N, phosphorus pentoxide (P_2O_5) and potassium oxide (K_2O)

respectively in L_1 . The corresponding dose in L_2 strip was 200–160–200 kg ha⁻¹. L_0 strip was kept as control and no inorganic fertilizer was applied. Fodder maize was grown as exhaust crop with different seed rates in different strips. In this way, fertility gradient was created in the strips which were evident from varying fodder yield and different soil fertility status in different strips.

STCR experiment: The main experiment was undertaken during winter season after the harvest of exhaust crop, and test crop selected for the main experiment was potato (*Kufri Jyoti*). The experiment was laid out in a fractional factorial design comprising 21 treatments with four levels of nitrogen (0, 100, 200 and 300 kg N ha⁻¹), four levels of phosphorus pent-oxide (0, 50, 100, 150 kg P₂O₅ ha⁻¹), four levels of potassium (0, 50, 100, 150 kg K₂O ha⁻¹) and three levels of farmyard manure (0, 5, and 10 tons of farmyard manure ha⁻¹). The main field was divided into three strips. Each strip was divided into three organic blocks. In each individual strip, 21 treatments were allotted, out of which seven treatments were allotted in each block. Eighteen fertilizer treatments and three controls were randomized in three blocks. This resulted into altogether sixty three (63) plots in three strips. Each individual plot was 7.5m × 2.4m. The source of inorganic fertilizers were urea, single superphosphate and muriate of potash. Phosphatic and potassic fertilizers were applied as basal while nitrogen was applied in 2 equal splits, 21 days after planting (DAP), i.e., during first earthing up and 40 DAP. During land preparation, FYM was applied @ 0, 5 and 10 t ha⁻¹. The moisture content of FYM was found to be 45.5% and nutrient content was 0.50% N, 0.30% P, 0.70% K, 0.019% S, 0.164% Fe, 0.0028% Zn, 0.0015% Mn and 0.00025% Cu on dry weight basis. Generally, winter season was preferred for potato planting. Weeding was done twice, once at 21 DAP and second one at 40 DAP.

Soil samples (0–0.15 m) were collected with the help of a soil auger from five random locations of each plot before sowing of test crop. Samples were then processed and analysed using standard procedures. Here, soil available nitrogen was estimated by alkaline KMnO₄ N (Subbiah and Asija, 1956) method whereas soil available P (Olsen P) and K (NH₄OAc K) were estimated by following well established methods (Olsen *et al.*, 1954; Hanway and Heidel, 1952). Plant samples were processed and analysed for estimating concentration of nutrients (N, P and K) following the procedure given by Tandon (2001). Potato tuber yield, nutrient uptake and soil test values were considered for determining nutrient requirement (NR) (kg q⁻¹), percentage contribution from the soil available nutrients (CS %), percentage contribution from the applied fertilizer nutrients (CF %) and also percent contribution from FYM (CFYM %).

Basic parameters, i.e., nutrient requirement (NR), contribution of nutrients from soil (CS) and fertilizers (CF) were calculated as described by Ramamoorthy *et al.* (1967). The percent contribution of nutrients from applied FYM, viz., CFYM was estimated as described by Santhi *et al.* (1999). These basic data were utilized to formulate targeted yield equation, which was

used for fertilizer recommendation. To calibrate the fertilizer adjustment equations, soil, efficiency fertilizer and farmyard manure were derived and requirement of nutrient to produce unit quantity of potato tuber were estimated following the procedure of Rao and Srivastava (2000). Relationship between crop yield response, soil test values and fertilizer doses were derived by standard regression procedure (Draper and Smith, 1998). In this study, variations in potato tuber yield due to application of inorganic fertilizer were taken into consideration keeping aside other management practices and soil factors.

Field verification trial: A field verification trial was conducted to validate the fertilizer adjustment equation and the estimated fertilizer doses to obtain the targeted yield of potato tuber. The trial was conducted for two consecutive years (2017 and 2018). Seven treatments were selected for undertaking the trial in five fields of farmer's located at Bhabanipur village of Nadia district, West Bengal. The treatments comprised of control, farmer's practice, general recommended dose (GRD), STCR based yield target of 22 t ha⁻¹ with and without FYM and STCR based yield target of 24 t ha⁻¹ with and without FYM. Standard agronomic practices were followed for growing potato. The treatments were laid out in randomized block design. Tuber yield of potato was statistically analysed.

Results and Discussion

Among three fertility gradient stripes, soil test values for N, P and K were maximum in L_2 strip. The higher values of soil available nutrients in L_2 strip might be attributed to higher application of inorganic fertilizers and lower seed rates. Soil available nutrients increased from L_0 to L_2 strips. Mean available soil N values from L_0 to L_2 strips were 225, 241 and 264 kg ha⁻¹. Corresponding values for soil available P were 49, 53.6 and 58.5 kg ha⁻¹ and those of K were 177, 210 and 242 kg ha⁻¹, respectively. The mean yield values of potato tuber and nutrient uptake by potato are presented in Table 1. Potato tuber yield ranged between 10.1 to 29.2 t ha⁻¹. The mean potato tuber yield value was 21.2 t ha⁻¹. The lowest potato yield and uptake of nutrient by potato was recorded in strip L_0 . The highest yield and nutrient uptake values were recorded in L_2 strip.

The greatest tuber yield recorded in high fertility gradient (L_2 strip) clearly indicated that high fertility status favoured potato production. The mean uptake of N by potato in L_0 , L_1 and L_2 strips varied and the values were 138, 139 and 151 kg ha⁻¹. The corresponding values for mean P and K uptake values were 24.3, 28.8 and 32.3 kg ha⁻¹ and 160, 168 and 189 kg ha⁻¹ in L_0 , L_1 and L_2 strips, respectively. The response of tuber yield to added nutrients, i.e., applied inorganic N, P and K fertilizer was significant ($P < 0.01$). However, the response of potato yield to FYM application was not significant (Fig. 1). To evaluate tuber yield variation due to application of varied dose of inorganic fertilizers, relationship of tuber yield with N, P and K were evaluated by regression analysis. Regression analysis revealed that N alone was responsible for 87%

Table 1: Range and mean values of yield of potato tuber and N, P, K uptake in relation to different soil fertility strip

Particulars		L ₀	L ₁	L ₂
Tuber yield (t ha ⁻¹)	Range	10.1-26.9	10.6-27.4	11.2-29.2
	Mean	20.5	21.4	21.7
	SD	4.4	4.7	4.6
	CV (%)	21.4	22.0	21.3
N uptake (kg ha ⁻¹)	Range	62-167	64-177	66-193
	Mean	138	139	151
	SD	33.2	33.0	38.7
	CV (%)	24.0	23.7	25.6
P uptake (kg ha ⁻¹)	Range	9.5-31.0	11.0-38.2	13.0-43.9
	Mean	24.3	28.8	32.3
	SD	5.6	7.1	7.7
	CV (%)	23.1	24.6	23.9
K uptake (kg ha ⁻¹)	Range	95-192	105-210	121-218
	Mean	160	168	189
	SD	29.3	29.4	29.6
	CV (%)	18.3	17.5	15.7

L₀: Control; L₁: N: P₂O₅: K₂O: 100: 80:100; L₂: N: P₂O₅: K₂O: 200:160:200

Table 2: Basic data for calculating optimum fertilizer dose for potato cultivation

Nutrients	Basic data				
	NR (kg q ⁻¹)	CS (%)	CF (%)	CFYM (%)	Fertilizer Prescription Equation
N	0.67	33.98	42.41	14.02	FN = 1.58T - 0.80SN - 0.33OM
P	0.13	29.76	39.37	7.81	FP = 0.34T - 0.76SP - 0.20OM
K	0.83	55.07	100.88	7.07	FK = 0.82T - 0.55SK - 0.07OM

NR is nutrient requirement of N or P₂O₅ or K₂O kg q⁻¹ produce, CS is percent contribution from soil, CF is percent contribution from fertilizer, CFYM is percent contribution from FYM, FN, FP and FK are fertilizer N, P₂O₅ and K₂O (kg ha⁻¹) respectively. OM is organic matter; here it is FYM (t ha⁻¹)

SN, SP and SK are soil-test values (kg ha⁻¹) for potassium permanganate KMnO₄-extractable N, Olsen's P and ammonium acetate-extractable K, respectively, and T is targeted yield in the equation in t ha⁻¹.

variability in potato tuber yield. Absorption of nutrient and assimilation by plant was found better in case of applied nitrogen which might be due to mobile nature of nitrogen. This in turn accounted for greater crop yield in case of nitrogen. Incorporation of FYM along with N could explain 91% variability in tuber yield. The combined application of N, P, K and FYM were better in increasing tuber yield as compared to individual application of nutrients and explained 93% variability in tuber yield.

Potato tuber yield and total nutrient (N, P and K) uptake recorded a good relationship (Fig. 2). Nutrient requirement (NR) is defined as nutrient required for producing unit quantity of yield. Crop biomass production is influenced by the quantity of nutrient absorbed by the crop. To produce one quintal of potato tuber amount of nutrient needed was estimated as 0.67 kg N, 0.13 kg P and 0.83 kg K (Table 2). Potassium requirement was maximum in potato followed by N and P, which might be due to greater uptake of potassium. Fig. 2 shows a linear relationship between potato

tuber yield and N, P, K uptake. Similarly, other workers also derived relation between yield and nutrient uptake for other crops at different places. Bera *et al.* (2006) estimated the nutrient requirement of 1.48 kg N, 1.05 kg P₂O₅ and 1.86 kg K₂O for producing one quintal of rice grain in alluvial soil of West Bengal. On the other hand, the amount of nutrients required to produce one quintal of jute, rice and garden pea was 2.88, 2.34 and 0.52 kg N; 0.97, 0.47 and 0.11 kg P; 5.07, 3.48 and 0.39 kg K, respectively (Singh *et al.*, 2015).

Contribution of nutrients (N, P and K) from fertilizer sources was 42.41% for N, 39.37% for P and 100.88% for K (Table 2). On the other hand, efficiency of soil available nutrients for potato was recorded as 33.98, 29.76 and 55.07% for N, P and K, respectively. Results indicated that contributions to potato tuber yield from fertilizer sources were higher than those from soil source. Saren *et al.* (2017) also reported similar findings while experimenting with black gram. Efficiency of applied nitrogenous

Table 3: Field verification trials of fertilizer prescription equations of potato in inceptisols of Nadia district, West Bengal

Treatments	Fertilizer doses (kg ha ⁻¹)			Yield (t ha ⁻¹)	Addln yield over FP (t ha ⁻¹)	Yield response (kg kg ⁻¹ fertilizer use)	Gross income	Cost of fertilizer (Rs.ha ⁻¹)	Cost of cultivation	Net return	Yield deviation (%)	B:C ratio
	N	P ₂ O ₅	K ₂ O									
Control	0	0	0	8.00		0.0	63760	0	71250	0		
Farmer's practice	165	156	156	19.4		23.8	154419	14100	85350	69069		0.81
GRD	200	100	100	20.8	1.43	32.0	165776	10461	81711	84065		1.03
STCR (22 t ha ⁻¹)	167	54	95	23.7	4.30	49.6	188690	7584	78834	109855	7.6	1.43
IPNS-STCR (22 t ha ⁻¹)	165	53	95	24.0	4.68	51.3	191679	7503	78753	112926	9.3	1.58
STCR (24 t ha ⁻¹)	199	61	112	25.9	6.53	48.3	206423	8804	80054	126369	7.9	1.63
IPNS-STCR (24 t ha ⁻¹)	197	60	111	26.4	6.98	49.9	210010	8723	79973	130037	9.8	
CD 0.05			0.29									

B/C ratio; benefit-cost ratio (Rs Re⁻¹) based on net return basis; RDF: Recommended dose of fertilizer; ST-TY: Soil test and target yield based fertilizer and IPNS: Integrated plant nutrition system

Table 4: Ready reckoner of soil test and targeted yield (ST-TY) based fertilizer doses for potato

Available soil nutrients			Fertilizer nutrient required (kg ha ⁻¹)			Fertilizer nutrient required (kg ha ⁻¹)		
STVN	STVP	STVK	Targeted yield (22 t ha ⁻¹)			Targeted yield (24 t ha ⁻¹)		
175	5	125	199	68	111	231	74	127
200	10	150	179	64	97	211	71	113
225	15	175	159	60	83	191	67	100
250	20	200	139	56	70	171	63	86
275	25	225	119	52	56	151	59	72
300	30	250	99	49	42	131	55	59
325	35	275	79	45	29	111	52	45

fertilizer becomes very low as applied nitrogenous fertilizer is prone to loss from the soil in various ways such as leaching, denitrification, surface run-off, volatilization etc. (Cho, 2003; Freney *et al.*, 1990; Ponnamperna, 1972). Similarly, applied phosphatic fertilizer is also subject to fixation due to reaction with different cations in the soil and, thus, become unavailable to plants. Water soluble phosphatic fertilizers, when applied to soil, reacts with different cations like Ca, Mg, Fe or Al and make complex compounds which become insoluble and unavailable to plants (Prasad and Power, 2000). Lower efficiency of applied phosphatic fertilizers might be attributed to this phenomenon. On the other hand, efficiency of applied potassic fertilizer was recorded high, which might be due to higher plant uptake of this nutrient. Biomass and bulking rate of potato tuber is positively affected by potassium as it has an important role in synthesis and accumulation of starch in potato. Potassium, the most efficient monovalent cation, stimulates the activity of starch synthase

enzyme and catalyses the incorporation of simple glucose molecules into complex molecules of starch (Moinuddin *et al.*, 2004; Karam *et al.*, 2011). Overall growth of potato including accumulation of starch, cell and tissue growth of tubers is enhanced by potassium (Singh and Singh, 1996). Potassium has higher contribution among the fertilizer sources which might be due to luxury consumption of K and interactive effect of high doses of N, P₂O₅ and K₂O. Efficiency of organic source (FYM) was found to be 14.02% for N, 7.81% for P and 7.07% for K in potato crop. Contribution of soil and fertilizer sources for jute crop 18.82% and 34.86% for N, 21.11% and 43.65% for P and 45.61% and 171.61% for K as reported by Singh *et al.* (2015) in alluvial soils of Eastern India. Similarly, in garden pea, contribution from soil and fertilizer sources were recorded as 10.6% and 24.4% for N, 5.07% and 16.86% for P and 10.52% and 28.39% for K, respectively. Basic parameters (viz., nutrient requirement and contribution from soil, fertilizer and organic sources) were

Fig. 1: Relationship between potato tuber yield and addition of N, P, K and FYM at various doses.

estimated based on pre-sown soil test values, nutrient uptake by crop and crop yield. Based on these basic parameters, fertilizer adjustment equations could be derived for potato to get definite yield target (Table 2).

Lower fertilizer doses required for getting desirable yield targets under IPNS based STCR equation. Might be due to addition of FYM in IPNS system, which resulted in reduction of N, P and K fertilizers for getting desired yield targets. Application of FYM not only reduced the fertilizer requirement but also improved soil quality and maintained soil health (Biswas *et al.*, 2018). Verification trials were conducted in the farmer's field with the

objective to test the validity of targeted yield equations derived on the basis of the results obtained from STCR main field experiment before recommending the fertilizer prescription to farmers. This STCR approach is undertaken for greater profitability for farmers and improved efficiency of fertilizer recommendation based on soil test and targeted yield instead of general recommended dose. The results obtained from field verification trials are furnished in Table 3. Seven different treatments were verified in the farmer's field trial for two consecutive years. Out of these treatments, soil test and targeted yield based fertilizer application and general recommendation recorded significantly greater yield over farmer's practice and no-input control. On the other hand,

Fig. 2: Relationship between potato tuber yield and plant uptake of N, P and K nutrients.

fertilizer application based on farmer's practice and control were less efficient in producing tuber yield of potato. Deviation in tuber yield obtained from targeted yield equation ranged from (+) 7.6% to (+) 9.8%, which were within $\pm 10\%$ deviation of yield target. It was observed that net monetary return and benefit-cost ratio were higher where fertilizers were applied based on soil-test and target yield approach, either alone or in combination with FYM. Application of fertilizer based on soil test and targeted yield was superior over fertilizer application based on farmer's practice and general recommended dose. Integration of FYM (5 t ha⁻¹) along with inorganic fertilizers as derived from soil test values and targeted yield (24 t ha⁻¹) equation recorded higher response ratio (49.9 kg kg⁻¹ NPK) and B: C ratio (1.63) over general recommended

dose (32 kg kg⁻¹ NPK, with B: C ratio 1.1). Between the two targets verified, targeting for lower yield, i.e., 22 t ha⁻¹ recorded relatively higher response ratio than 24 t ha⁻¹ due to better use efficiency of applied NPK fertilizers at low yield target levels.

The results are in accordance with Bera *et al.* (2006) and Sharma *et al.* (2015) who also reported improved benefit-cost ratio through soil test as based fertilizer application as compared to GRD and farmer's practice while working on rice. Similar positive effect of soil test based fertilizer application on better benefit-cost ratio as compared to general recommended dose and farmer's practice was observed by Bhaduri and Goutam (2013) in wheat and Saxena *et al.* (2008) in onion. To help farmers

having different economic conditions and different soil resources a ready reckoner has been prepared for potato based on the fertilizer prescription equation for obtaining different yield targets. This clearly indicates that fertilizer N, P_2O_5 and K_2O decreased with increase in soil test values. By following ready table for a yield target of 22 t ha^{-1} tuber yield with soil-test values of 250:35:200 $KMnO_4$ N, Olsen P and NH_4OAc K, a farmer can save 61 kg N, 55 kg P_2O_5 and 44 kg K_2O per hectare over general recommended dose, approximately equal to Rs. 4800/- per hectare. This will help the farmers as well as extension workers to determine proper fertilizer doses to obtain maximum economic yield (Table 4).

STCR approach discussed in this study will improve potato tuber yield in the Gangetic alluvial soil of Eastern India. This will immensely help to resource poor farmer's in increasing crop yield and also reduce the cost of cultivation by increasing fertilizer use efficiency and saving costly fertilizers.

Acknowledgments

This research was supported by ICAR through AICRP on STCR. We thank the Director of ICAR-CRIJAF for providing facilities and encouragement for this study.

References

- Ahmed, S., M. Riazuddin and P.V. Krishna Reddy: Optimizing fertilizer doses for rice in alluvial soils through chemical fertilizers, farm yard manure and green manure using soil test values. *Agropedology*, **12**, 133–40 (2002).
- Bera, R., A. Seal, P. Bhattacharyya, T.H. Das, D. Sarkar and K. Kangjoo: Targeted yield concept and a framework of fertilizer recommendation in irrigated rice domains of subtropical India. *J. Zhejiang Univ. Sci. B.*, **7**, 963–968 (2006).
- Bhaduri, D. and P. Gautam: Optimization and validation of targeted yield equation-based fertilizer doses under INM for wheat in tarai region of Uttarakhand, India. *Indian J. Agr. Sci.*, **47**, 16–25 (2013).
- Biswas, S., D.K. Kundu, S.P. Mazumdar, A.R. Saha, B. Majumdar, A.K. Ghorai, D. Ghosh, A.N. Yadav and A.K. Saxena: Study on the activity and diversity of bacteria in a New Gangetic alluvial soil (Eutrocept) under rice-wheat jute cropping system. *J. Environ. Biol.*, **39**, 1–7 (2018).
- Brajendra, P. and L.S. Singh: Soil test based fertilizer recommendation and verification for maize grown in mid hills of Meghalaya. *Asian J. Soil Sci.*, **7**, 124–26 (2012).
- Cho, J.Y.: Seasonal runoff estimation of N and P in a paddy field of Central Korea. *Nutr. Cycl. Agroecosys.*, **65**, 43–52 (2003).
- Dobermann, A. and P.F. White: Strategies for nutrient management in irrigated and rainfed lowland rice systems. *Nutr. Cycl. Agroecosys.*, **53**, 1–18 (1998).
- Draper, N.R. and H. Smith: Applied Regression Analysis. New York. Wiley (1998).
- FAOSTAT: Production: Potatoes. Food and Agriculture Organization of the United Nations, Rome (2014).
- Fernandes, A.M., R.P. Soratto and B.L. Silva: Extração e exportação de nutrientes se m cultivares de batata: I-Macronutrientes. *The Revista Brasileira de Ciência do Solo*, **35**, 2039–2056 (2011).
- Freney, J. R., A. C. F. Trevitt, S. K. D. Datta, W. N. Obcemea and J. G. Real: The interdependence of ammonia volatilization and denitrification as nitrogen loss processes in flooded rice fields in the Philippines. *Biol. Fert. Soils*, **9**, 31–36 (1990).
- Hanway, J.J. and H. Heidel: Soil analyses methods as used in Iowa state college soil testing laboratory. *Iowa Agriculture*, **57**, 1–31 (1952).
- Karam, F., R. Massaad, S. Skaf, J. Breidy and Y. Rouphael: Potato response to potassium application rates and timing under semi-arid conditions. *Adv. Hort. Sci.*, **25**, 265–268 (2011).
- Mazumdar, S.P., A.R. Saha, B. Majumdar, M. Kumar, S. Biswas, S. Mitra, R. Saha, S. Sasmal and R. Bhattacharya: Soil test based optimal fertilizer doses for attaining different yield targets of jute in alluvial soils of West Bengal. *J. Crop Weed*, **14**, 20–27 (2018).
- Moinuddin, S., S.K. Bansal and N.S. Pasricha: Influence of graded levels of potassium fertilizer on growth, yield and economic parameters of potato. *J. Plant Nutr.*, **27**, 239–259 (2004).
- Olsen, S.R., C.V. Cole, F.S. Watanable and L.A. Dean: Estimation of available phosphorus in soils by extracting with sodium bicarbonate (Circular No. 939). U.S. Department of Agriculture, Washington (D.C.) (1954).
- Pandey, S.K., S.V. Singh and D. Sarkar: Potato (*Solanum tuberosum*) for sustaining food and nutrition security in developing world. *Indian J. Agr. Sci.*, **75**, 3–18 (2005).
- Ponnamperuma, F. N.: The chemistry of submerged soils. *Advances in Agronomy*, **24**, 29–96 (1972).
- Pradhan, N. K., A. Mishra, G.P. Padhy and B. Jena: Soil test based fertilizer recommendation for targeted yield of groundnut (*Arachis hypogaea*) under rice–groundnut cropping system in an Inceptisol of Orissa. *Environ. Eco.*, **25**, 478–480 (2007).
- Prasad, R. and J.F. Power: Soil fertility management for sustainable agriculture. Boca Raton, FL: CRC Press (2000).
- Ramamoorthy, B., R.L. Narasimham and R.S. Dinesh: Fertilizer application for specific yield targets of Sonora 64. *Indian Farming*, **17**, 43–44 (1967).
- Rao, S. and S. Srivastava: Soil test based fertilizer use - A must for sustainable agriculture. *Fertilizer News*, **45**, 25–38 (2000).
- Reshi, M., A. Bhat, R.K. Kaul and M. Gupta: Evaluation of various potato cultivars of Jammu region for processing attributes. *Bioscan*, **8**, 1203–1205 (2013).
- Santhi, R., G. Selvakumari and R. Perumal: Soil test- based fertilizer recommendations under integrated plant nutrition system for rice–rice–pulse cropping sequence. *J. Indian Soc. Soil. Sci.*, **47**, 288–94 (1999).
- Saren, S., A. Mishra and P. Dey: Integrated nutrient management and formulation of targeted yield equations for black gram (*Vigna mungo* L.). *Curr. Sci.*, **113**, 314–317 (2017).
- Saxena, A.K., S. Singh, A. Srivastava and P. Gautam: Yield target approach under integrated nutrient management for assessing fertilizer requirements of onion in Mollisols of Uttarakhand. *Indian J. Hortic.*, **65**, 302–306 (2008).
- Sharma, G.K., V.N. Mishra, G.R. Maruti Sankar, S.K. Patil, L.K. Srivastava, D.S. Thakur and Ch. Srinivasa Rao: Soil-test-based optimum fertilizer doses for attaining yield targets of rice under midland Alfisols of Eastern India. *Commun. Soil Sci. Plant Anal.*, **46**, 2177–2190 (2015).
- Singh, S.R., D.N. Maitra, D.K. Kundu, B. Majumdar, A.R. Saha and B.S. Mahapatra: Integrated fertilizer prescription equations for recommendations of fertilizers in jute–rice–garden pea sequence on Alluvial soil of Eastern India. *Commun. Soil Sci. Plant Anal.*, **46**, 1–15 (2015).
- Singh, V.N. and S.P. Singh: Influence of split application of potato. *J. Indian Potato Assoc.*, **23**, 72–74 (1996).
- Solaiappan, U., G.R. Maruthi Sankar and V. Subramanian: Soil-test based optimal fertilizer N recommendation for sustainable sorghum (*Sorghum bicolor*) yield in semi-arid vertic inceptisols of Tamil Nadu. *Indian J. Agr. Sci.*, **78**, 285–292 (2008).

- Subbiah, B.V. and G.L. Asija: A rapid procedure for the determination of available nitrogen in soils. *Curr. Sci.*, **25**, 259–260 (1956).
- Tandon, H.L.S.: Methods of Analysis of Soils, Plants, Waters and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India (2001).
- Truog, E.: Fifty years of soil testing. In: Transactions of Seventh Int. Congress Soil Sci., Vol. **3**, Commission IV, Paper No. 7, pp. 46–53 (1960).
- Verma, M., Y.V. Singh, P. Dey and A. Babu: Soil test based fertilizer recommendation for mustard (*Brassica juncea* L.) in Eastern plain zone of Uttar Pradesh, India. *IJCMAS*, **6**, 155-161 (2017).
- Witt, C., A. Dobermann, S. Abdulrachman, H.C. Gines, G.H. Wang, R. Nagarajan, S. Satawathananont, T.T. Son, P.S. Tan and L.V. Tiem: Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. *Field Crop Res.*, **63**, 113–38 (1999).

Online
COPY