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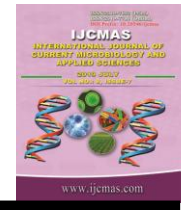

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Fertilizer Recommendations based on Targeted Yield Concept Involving INM for Potato (*Solenum Tuberosum* L) in Inceptisols of Rainfed Midlands of Bastar Plateau

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Soil test crop response correlation study was carried out in midland inceptisols of Bastar plateau zone of Chhattisgarh (India) during 2012-13 taking potato (*kufri pukhraj*) as test crop to quantify production in the context of the variability of soil properties and recommendation of balanced fertilizers with organic manure based on targeted yield concept. The basic data required for formulation of fertilizer recommendation is derived from this experiment. Nutrient required to produce one quintal of potato tuber was found to be 0.48 kg N, 0.11 kg P and 0.52 kg K, respectively. The fertilizer efficiencies of N, P and K for potato crop were estimated as 32.94, 28.30 and 97.40 per cent, respectively. The efficiencies of soil test values were 16.42, 64.47 and 18.33 per cent for N, P and K, respectively. The efficiencies of organic source (FYM) were observed as 11.09, 5.88, 5.55 per cent for N, P and K, respectively. With the help of above basic data base, the fertilizer recommendation equations and the ready reckoner was developed which will be useful for soil test based balanced and integrated nutrient management in potato crop under midlands and other similar soil and agro-climatic conditions.

Introduction

India is the third largest producer of potato (*Solanum tuberosum* L.) in the world after China and Russia. The average productivity of potato in India and Chhattisgarh state is 22.70 and 16.8 t ha^{-1} respectively (Anonymous, 2011). In Bastar region, with limited irrigation facility, potato is gaining popularity due to favourable climate (Sharma and Chaudhary, 2014). It is a heavy feeder of plant nutrients having high requirement of nitrogen, phosphorus, potassium and other nutrients. To increase the crop productivity, use of high-yielding varieties with optimum levels of inputs is very much needed, but the decision on fertilizer use would require an in-depth knowledge of the expected crop yield response to nutrient application, which is a function of crop nutrient needs, supply of nutrients from indigenous sources, and the short and long-term fate of the fertilizer doses applied to a soil (Doberman *et al.,* 2003). In the light of ever-increasing prices coupled with increasing demand of chemical fertilizers and depleting soil fertility with respect to availability of different nutrients, there is an urgent need to shift to integrated organic and inorganic sources of nutrients for sustainable crop production and soil health (Singh *et al.*, 2014 and Kumar *et al.*, 2014).

Several approaches have been used for fertilizer recommendation based on chemical soil test so as to attain maximum yield per unit of fertilizer use. Among the various approaches, the target yield approach given by Troug (1960), which was further modified by Ramamoorthy *et al.*, (1967) has found popularity in India (Subba Rao and Srivastava, 2000). The data obtained from the targeted yield experiment provides a range in soil test values, nutrient uptake and yield levels which enable in calculating the 4 basic parameters as nutrient requirement, per cent contribution of available nutrient from soils (CS), the per cent contribution from the applied fertilizer (CF) and the per cent contribution from organic manures (CFYM).

Quantitative fertilizer requirements based on this approach have been estimated for specific yield target of crops like maize, rice and chickpea (Mandal *et al.,* 2016; Sharma *et al.,* 2015; Mishra *et al.,* 2015; Regar and Singh, 2014). Recommendations based on Soil Test Crop Response Correlation concept are more quantitative, precise and meaningful because combined use of soil and plant analysis is involved in it. It gives a real balance between applied nutrients and the available nutrients already present in the soil. Keeping above factors in view and lack of quantitative information on fertilizer doses with organic manures based on target yield for '*Kufri pukhraj*' potato in Bastar plateau of Chhattisgarh, this study was conducted.

Materials and Methods

A field experiment was conducted based on STCR methodology on potato with the variety '*kufri pukhraj*' at Shaheed Gundadhoor College of Agriculture and Research Station, Kumharawand, Jagdalpur, Bastar district of Chhattisgarh (India) during *Rabi* season, 2013–14 after harvest of maize experiment during kharif season, 2013. The field was prepared without any disturbance to the already created three fertility gradient strips (L_0, L_1, and L_2). Then each strip was sub divided into 24 plots of equal size. A set of 24 treatments out of which 21 treatments in combination with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}), four levels of phosphorus (0, 30, 60 and 90 kg ha^{-1}) four levels of potassium (0, 30, 60 and 90 kg ha^{-1}) and three levels of FYM (0, 5, 10 t ha^{-1}) and three controls were superimposed to different plots in each strip and the experiment was conducted in a randomized block design (RBD). Initial soil samples were collected from each sub-plot (0-15cm) before superimposition of 21 fertilizer treatments and three controls were analyzed for available nitrogen by alkaline potassium permanganate method as proposed by Subbiah and Asija (1956), available phosphorus by Bray's method (Bray, 1948) and available potassium by ammonium acetate method (Hanway and Heidal, 1952) as described by Jackson (1973). The plant samples tuber as well as straw collected at harvesting stage has been analyzed for N, P and K and the plant uptake of nutrients was calibrated by using tuber and straw yield data. Nitrogen content of plant samples was determined using method as described by Chapman and Pratt (1961), Phosphorus content was determined by vanadomolybdo-phosphoric acid yellow color complex method as described by Jackson (1973) and Potassium content was determined by flame photometer as described by Chapman and Pratt (1961).

Using the tuber yield and nutrient uptake data, soil test values and applied fertilizer does of treated and control plots, the basic data viz.

nutrient requirement (NR) (kg q^{-1}), percent contribution from the soil available nutrients [CS, %] and the percent contribution from the applied fertilizer nutrients [CF, %] were derived and used to calibrate the fertilizer adjustment equations (Velayutham *et al.*, 1985a; Rao and Srivastava, 2000).

$$F = \frac{NR}{Cf} Y - \frac{Cs}{Cf} S - \frac{CFYM}{Cf} FYM$$

Where,

F =Fertilizer (kg ha^{-1}), NR =Nutrient requirement of N or P_2O_5 or K_2O kg q^{-1} produce, Cs = Per cent contribution from soil, Cf =Per cent contribution from fertilizer, CFYM =Per cent contribution from FYM, S = Soil test value for available N, P or K (kg ha^{-1}), Y=Yield target (q ha^{-1}) and FYM=Farmyard manure (t ha^{-1})

Standard regression procedure was used to relate the soil test and fertilizer with crop yield response (Draper and Smith, 1998). The nutrient requirement, soil, fertilizer and farm yard manure efficiencies were derived as discussed by Velayutham *et al.*, (1985b) and Maruthi Sankar (1986). The experiment was conducted on the basis of whole field method in which the data of all plots were used in deriving the estimates. The soil efficiency was estimated from only unfertilized plots, while the fertilizer and organic manure efficiency was estimated from fertilized plots.

The nutrient requirement was estimated from both the fertilized and unfertilized plots. The computational procedure of basic data is well discussed in Ramamoorthy *et al.*, (1967). The estimates of basic data were used for developing fertilizer adjustment equations for deriving optimum fertilizer doses for achieving different yield targets. The soil test based fertilizer recommendations can be prescribed in the form of a ready reckoner for different yield targets.

Results and Discussion

Soil available nutrients

Soil samples from each plot were taken before conducting the main experiments and analyzed for available N, P and K. The range and mean soil test values of available N, P and K nutrients before sowing of experiment during *rabi* season 2013-14 are given in Table 1. The results showed that the available nitrogen ranged between 192 and 250 with a mean of 218 kg ha^{-1}, available phosphorus from 6.20 to 40.50 with a mean of 21.7 kg ha^{-1}, and available potassium between 169 and 320 with a mean of 246 kg ha^{-1}.

It is evident from the above data that wide variability has existed in the soil test values among fertility strips which is essential for developing a multiple regression model, basic data and targeted yield equations for calibrating the optimum fertilizer dose. The soil test data indicate that available N, P and K varied with different fertility strips although available N and K variations with respect to fertility strip were marginal however, available P variation in different strips were quite marked and it increased across the fertility strips.

Gradient with respect to available P was observed clearly due to immobile nature of P and fixed with soil constituents to form insoluble compounds depending on the nature of soil and thus remains in soil. However, there was no gradient created with respect to N and K as the nature of N in soil is very dynamic and its different forms are subjected to losses through leaching, volatilization and de-nitrification. Average K status of the experimental field soil was in medium level and maintenance of its dynamic equilibrium might be the possible reason for almost the same mean soil test K levels in all strips.

Tuber yield of potato

The range and average values of potato yields in relation to three fertility strips during *rabi* seasons 2013-14 are given in Table 1. The over all potato yields were recorded in the range from 56.82-205.92 q ha^{-1} with an average of 144.59 q ha^{-1}. There was an increasing trend in the tuber yields from L_0 to L_2 strip. It was observed that standard deviation (SD) and coefficient of variation (CV%) were higher in L_0 strip and declined under L_1 and L_2 strip indicating thereby that yield variations were higher in L_0 strip due to soil nutrients variation. The increase in potato tuber yields with respect to fertility strips may be due to fertility gradient in soil P status from L_0 to L_2.

Crop response to added fertilizer doses and FYM

The crop responses to fertilizer N, P, K and FYM have been depicted in Figures 1 to 4 which showed that good crop responses to the fertilizer N and P application were observed with potato whereas crop response to K application was less consistent. Crop response to FYM application was not quite marked as shown in Figure 4. The relation of potato yields with different plant nutrients as independent variables were derived by regression analysis to evaluate the yield variations due to various nutrients and presented in the Table 2. Results indicate that the larger proportion of variation in tuber yields of potato was accounted for by N alone. Higher crop responses were attributed to the high N requirement and being a mobile nature of this element, it is easily accessible to the plant in the root system sorption zone (Ramamoorthy *et al.*, 1967). Fertilizer P_2O_5 and K_2O were the next to explained the rest of variations. The P ions react very quickly with soil constituents to form insoluble compounds and are thus rendered immobile in the soil. Furthermore, the requirement of P nutrient in potato was lower than N. The curvilinear nature of potato yield responses to P application also did not reflect on yield variation due to poor R^2 value as compared to linear relationship. The yield variation due to FYM application was also accounted very poor correlation. However, 89.0 % of the yield variations were estimated due to fertilizer N and P only as reflected in the equation. Curvilinear relation of fertilizer N and P did not reflect on yield variations.

Relationship between yield and nutrient uptake and estimation of nutrient requirement (NR)

The yield of potato crop showed the close association with total N, P and K uptake (Table 3). This relation was used to estimate the nutrient requirement for potato (Table 3). The nutrient requirement is defined as the amount of nutrient required to produce per unit amount of yield. The nutrient requirement can be given by the regression coefficient (b_1) of yield (Y) and total nutrient uptake (U).

$$\mathbf{Y = b_1 U \quad or\ U = 1/b_1 * Y}$$

Where, $1/b_1$ gives the NR.

The amount of nutrients absorbed by the crop decides a definite amount of biomass production. Nutrient requirements for potato crop has been estimated based on conventional and regression methods which are almost similar values and are shown in the Table 3 and depicted graphically in Figures 5-7 showing a close association between crop yields and nutrient uptake with almost a linear relationship. The amount of nutrient required to produce one quintal of potato tuber was found to be 0.48 kg N, 0.11 kg P and 0.52 kg K. The nutrient requirement is also estimated by the conventional method as given below:

$$\text{NR (kg/q)} = \frac{\text{Total Nutrient Uptake (kg/ha)}}{\text{Grain Yield (q/ha)}}$$

Table.1 Range and mean values of initial soil available N, P and K and tuber yield of potato crop (variety- *Kufri pukhraj*)

Fertility strips	Minimum	Maximum	Mean	SD	CV (%)
Alkaline $KMnO_4$ –N (kg ha^{-1})					
L_0	192	243	214	13.11	6.13
L_1	192	250	220	15.72	7.15
L_2	194	238	221	12.53	5.67
All strips	192	250	218	14.04	6.44
Bray's-P (kg ha^{-1})					
L_0	6.2	29.4	15.8	6.30	39.87
L_1	8.9	35.7	20.8	7.01	33.70
L_2	15.2	40.5	28.5	6.82	23.93
All strips	6.2	40.5	21.7	8.45	38.94
NH_4OAc-K (kg ha^{-1})					
L_0	169	285	207	26.95	13.00
L_1	201	315	256	40.56	15.84
L_2	227	320	274	25.65	9.36
All strips	169	320	246	42.20	17.15
Potato Tuber Yield (q ha^{-1})					
L_0	56.82	205.92	134.18	44.33	33.04
L_1	64.34	201.07	146.29	42.77	29.24
L_2	68.38	204.82	153.31	44.38	28.95
All strips	56.82	205.92	144.59	43.94	30.39

Table.2 Selected regression model to account for yield variation of potato

S. No.	General regression models	R^2
1	Y = 80.31 + 0.597 FN	**0.731**
2	Y = 85.83 + 1.175 FP	**0.634**
3	Y = 107.5 + 0.800 FK	**0.277**
4	Y = 139.3 + 1.042 FYM	**0.009**
5	Y = 79.03 + 0.650 FN -0.000 FN^2	**0.731**
6	Y = 78.43 + 1.766 FP - 0.006 FP^2	**0.652**
	Nutrient substitution models	
7	Y=66.767+0.414FN +0.667 FP	**0.866**
8	Y=66.252 +0.411 FN +0.653 FP + 0.033FK	**0.867**
9	Y=61.039+ 0.411 FN + 0.653 FP + 0.033 FK + 1.043 FYM	**0.876**
10	Y = 75.10+ 0.59FN + 1.04FYM	**0.740**
11	Y =47.53 + 0.16 SN +0.57FN	**0.730**
12	**Y = 84.52+ 0.10SP + 1.15FP**	**0.630**

Where, FN, FP and FK are fertilizer N, P_2O_5, and K_2O (Kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg h^{-1}) for $KMnO_4$- N, Bray 's P and ammonium acetate extractable K and Y is crop yield.

Table.3 Relation of grain yield (Y) and total nutrient uptake (U), Nutrient requirement(NR), Efficiencies of fertilizer (E_f), soil (E_s), FYM (E_{org}) and Fertilizer Equations for potato

Nutrients	Y = b1 U	R^2	NR (kg q^{-1})	E_f (%)	E_s (%)	E_{org} (%)	Fertilizer Equations
N	Y = 2.065 UN	0.881	0.48	32.94	16.42	11.09	FN = 1.44 Y - 0.50 SN - 0.34 FYM
P	Y = 8.818 UP	0.693	0.11	28.30	64.47	5.88	FP = 0.39Y - 2.28 SP - 0.21 FYM
K	Y = 1.922 UK	0.922	0.52	97.40	18.33	5.55	FK = 0.53Y - 0.19 SK - 0.06 FYM

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$ -N, Bray's P and ammonium acetate extractable K and Y is crop yield in q ha^{-1}.

Table.4 Ready Reckoners for soil test based fertilizer N P_2O_5 and K_2O recommendation of potato (var. *Kufri Pukhraj*) in midland *Inceptisols* with 5 tons of FYM

Soil Test values (kg ha^{-1})			Yield Target of potato (q ha^{-1})								
			100			150			200		
N	**P**	**K**	**FN**	**FP**	**FK**	**FN**	**FP**	**FK**	**FN**	**FP**	**FK**
150	4	200	67	29	25	139	48	41	211	68	**68**
175	6	225	55	25	25	127	44	37	199	63	**63**
200	8	250	42	25	25	114	39	32	186	59	**58**
225	10	275	38	25	25	102	35	27	174	54	**54**
250	12	300	38	25	25	89	30	25	161	50	**49**
275	14	325	38	25	25	77	26	25	149	45	**44**
300	16	350	38	25	25	64	25	25	136	41	**39**
325	18	375	38	25	25	52	25	25	124	36	**35**
350	20	400	38	25	25	39	25	25	111	31	**30**
375	22	425	38	25	25	38	25	25	99	27	**25**
400	**24**	**450**	**38**	**25**	**25**	**38**	**25**	**25**	**86**	**25**	**25**

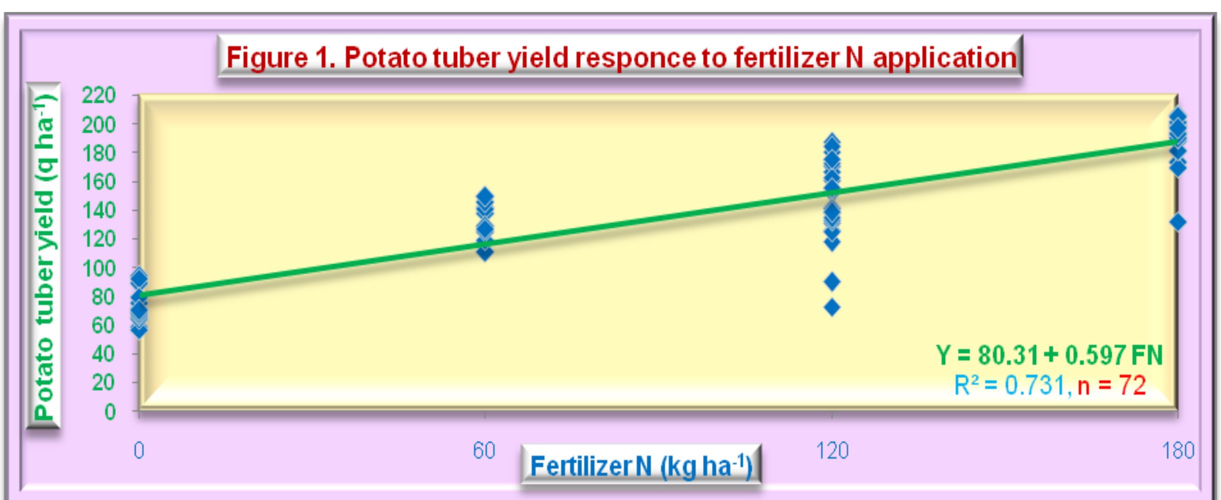

Figure 1. Potato tuber yield responce to fertilizer N application

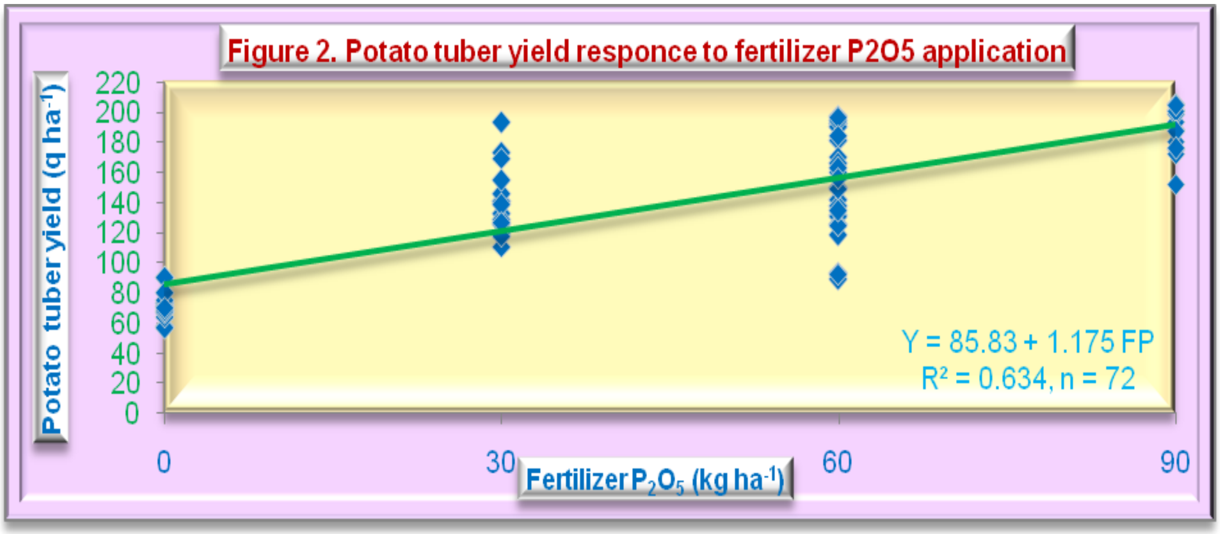

Figure 2. Potato tuber yield responce to fertilizer P2O5 application

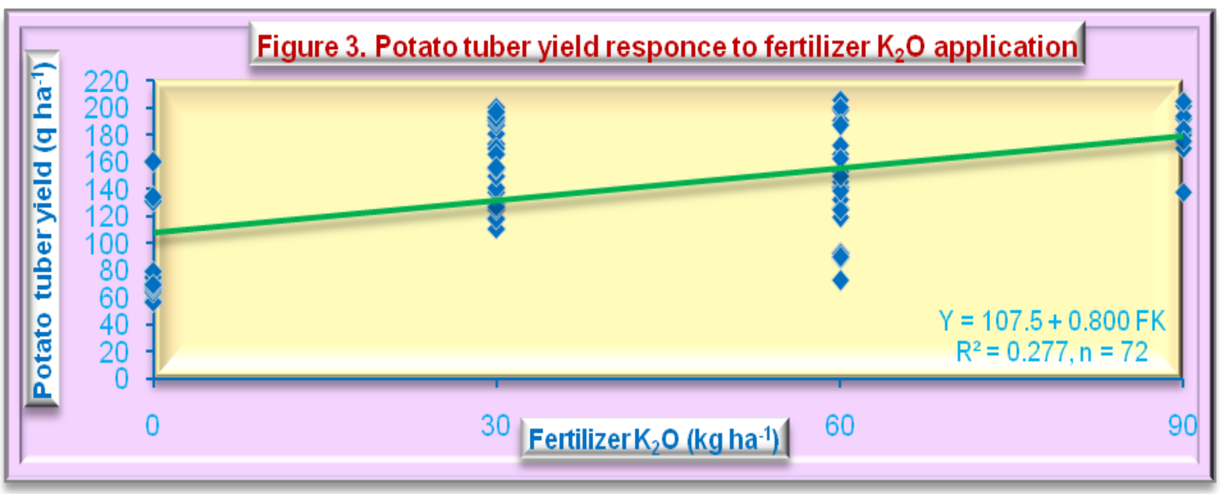

Figure 3. Potato tuber yield responce to fertilizer K_2O application

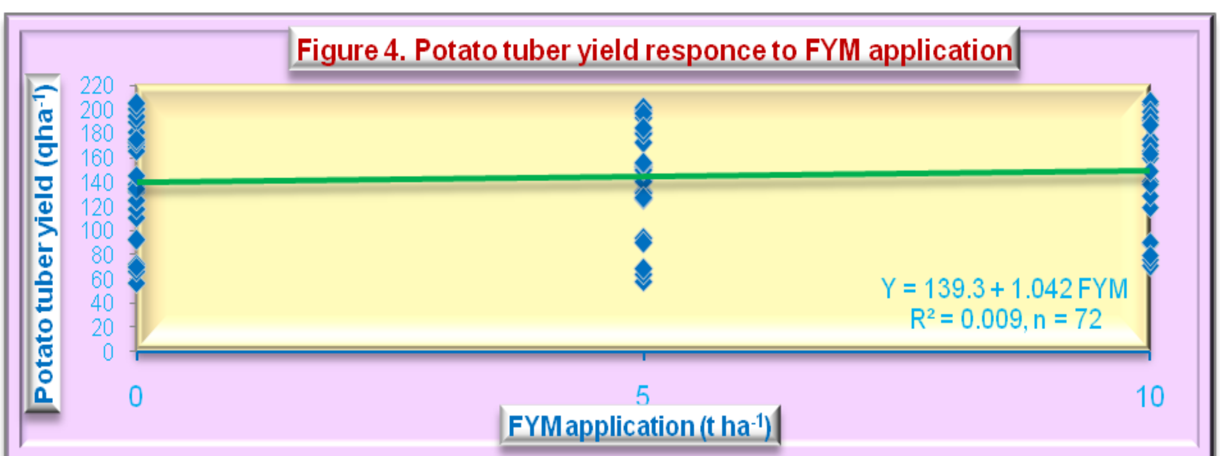

Figure 4. Potato tuber yield responce to FYM application

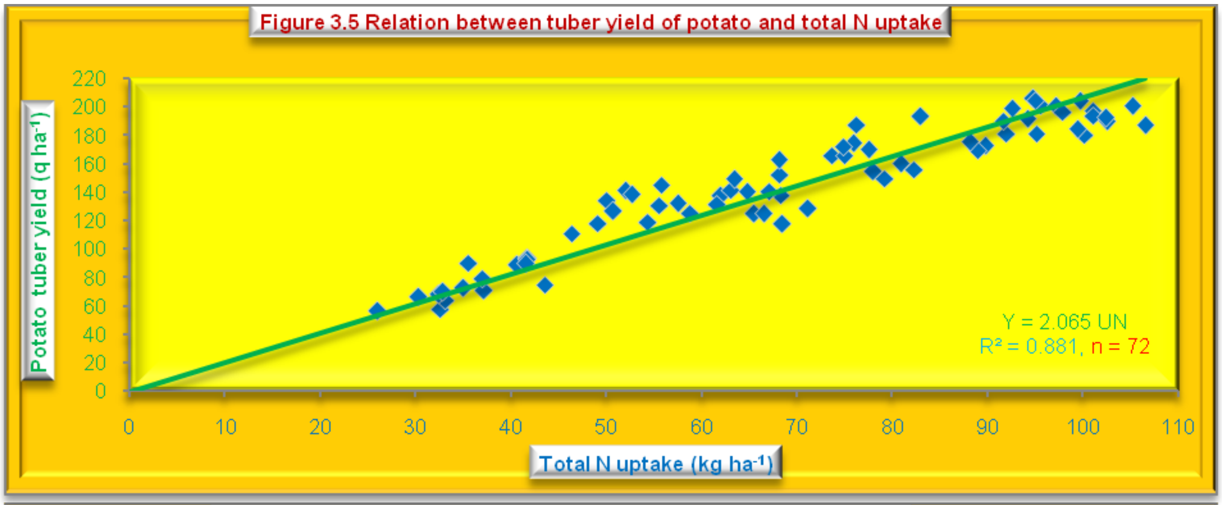
Figure 3.5 Relation between tuber yield of potato and total N uptake
Potato tuber yield (q ha-1)
Total N uptake (kg ha-1)
Y = 2.065 UN
R² = 0.881, n = 72
0
20
40
60
80
100
120
140
160
180
200
220
0
10
20
30
40
50
60
70
80
90
100
110

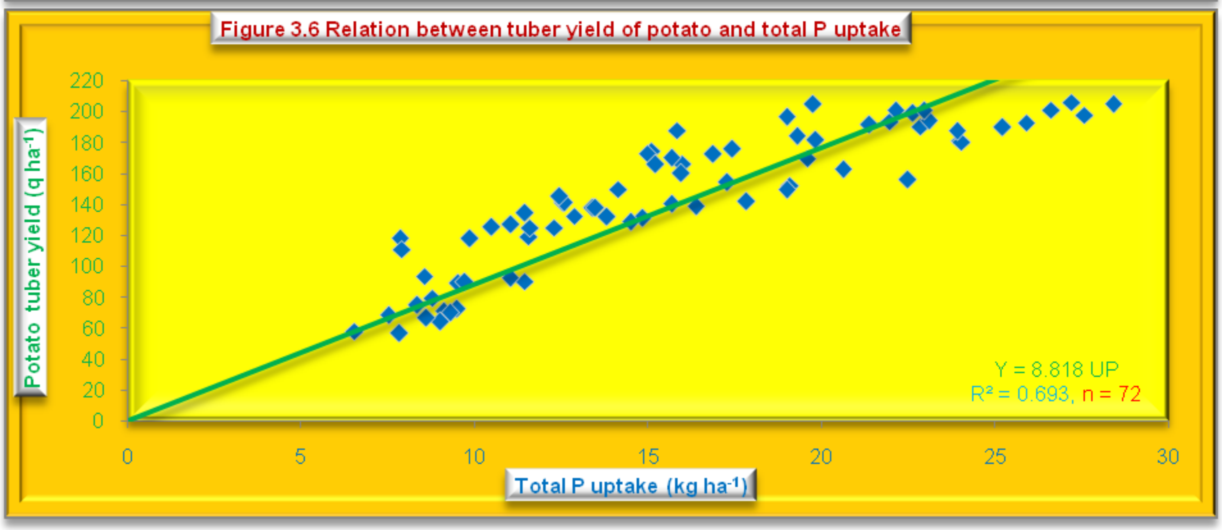
Figure 3.6 Relation between tuber yield of potato and total P uptake
Potato tuber yield (q ha-1)
Total P uptake (kg ha-1)
Y = 8.818 UP
R² = 0.693, n = 72
0
20
40
60
80
100
120
140
160
180
200
220
0
5
10
15
20
25
30

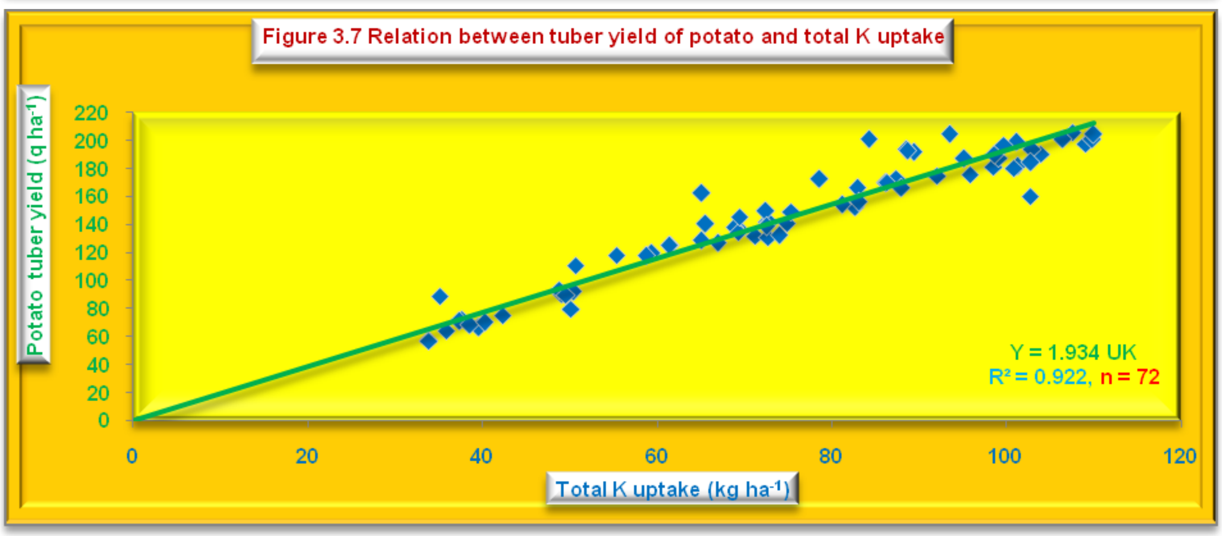
Figure 3.7 Relation between tuber yield of potato and total K uptake
Potato tuber yield (q ha-1)
Total K uptake (kg ha-1)
Y = 1.934 UK
R² = 0.922, n = 72
0
20
40
60
80
100
120
140
160
180
200
220
0
20
40
60
80
100
120

This parameter gives better results with the regression methods which are being followed in present study. Several workers have reported the nutrient requirement of different crops at various places. Ramamoorthy *et al.*, (1967) reported for wheat crop which required 2.5 kg N, 0.8 kg P_2O_5 and 1.0 kg K_2O for one quintal of grain production. Prasad *et al.,* (1981) estimated the nutrient requirement of sugarcane for the production of 1 tonne of cane as 1.71 kg N, 0.18 kg P_2O_5 and 1.80 kg K_2O. Bajendra *et al.,* (2012) reported that the nutrient requirement (kg q^{-1}) of N, P_2O_5 and K_2O were found to be 6.97, 1.42 and 1.04, respectively for producing one quintal of maize yield in Meghalaya. Suri and Verma (2000) found that amounts of nutrients needed to produce one quintal of maize and wheat were 2.30 and 2.35 kg N 0.81 and 0.63 kg P_2O_5 and 1.64 and 1.66 kg K_2O, respectively. Sharma *et al.,* (2015) reported the nutrient requirement of rice crop as 1.36 kg N, 0.31 kg P_2O_5 and 1.90 kg K_2O per quintal of rice grain produced in Bastar plateau of Chhattisgarh.

Efficiencies of fertilizer, soil test and FYM

The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of software developed by AICRP on STCR, Indian Institute of Soil Science, Bhopal (MP). The fertilizer efficiencies of N P and K for potato crop were estimated as 32.94, 28.30 and 97.40 per cent, respectively. The efficiencies of soil test for potato were recorded as 16.42% N, 64.47 %P and 18.33% K. The efficiencies of organic source (FYM) were observed as 11.09, 5.88, 5.55 per cent N, P and K for potato crops, respectively.

It is well known that approximate 2/3rd of the applied fertilizer N lost through leaching, volatilization, de-nitrification and by run-off. Similarly, a large fraction of applied fertilizer P is fixed in soil by reacting with dominant cations present in the soil like Fe, Mn, Ca, Mg etc. High efficiency of applied fertilizer K observed seems to be due to higher uptake of this nutrient as luxury consumption. Soil test efficiencies for N and K were recorded less than fertilizer sources and reverse trend was seen in case of soil test Ramamoorthy *et al.*, (1967) reported the efficiency of soil N, P and K were 37, 14 and 44.0 per cent, respectively and the efficiency of fertilizer N, P and K were 34, 41 and 36 per cent, respectively. Similarly Santhi *et al.,* (2004) reported the contribution of soil and fertilizer nutrients as 14.13 and 38.28 per cent for N, 35.33 and 56.61 per cent for P_2O_5 and 14.33 and 70.03 per cent for K_2O, respectively for onion bulb yield in *Inceptisols* of Tamil Nadu.

Estimation of fertilizer adjustment equations

Based on the basic parameters *viz.* nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM), fertilizer adjustment equations were evolved for potato crop to achieve a definite yield goal. The following equations (Table 3) were evolved for potato for fertilizer N, P_2O_5 and K_2O.

Ready reckoners chart for fertilizer recommendation to potato crop

The ready reckoners for potato with the use of 5 tonnes of FYM are shown in Table 4. The application of chemical fertilizer with FYM in integrated manner has beneficial effect by several ways in terms of soil fertility and physical properties improvement and higher fertilizer use efficiencies. It is further evident that the fertilizer requirements decreased with increase in soil test values. Therefore, a slightly lower yield target may be considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield target for a resourceful farmers who are interested for maximum potential production per unit area. Hence, for maintaining soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices that achieve the twin objectives of high yield and maintenance of soil fertility. Thus the targeted yield approach of fertilizer recommendation ensures nutrient balancing to suit the situations involving different yield goals, soil fertility and resources of the farmer (Dev *et al.,* 1985). Several workers have used this approach of fertilizer prescription Patil, (1985) and Acharya *et al.,* (2001).

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