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Fertilizer prescription for desired target yield of direct seeded rainfed upland rice in north eastern hill region

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ABSTRACT

An experiment was carried out to develop soil test crop response correlation based fertilizer prescription for direct seeded rainfed upland rice in soils of north eastern hill region. Field experiments were conducted with rice (Oryza sativa L.; cv. RC Maniphou 6) as gradient crop and also as test crop in two consecutive kharif seasons of 2010 and 2011, respectively. The fertility gradients were created with respect to nitrogen (N), phosphorus (P) and potassium (K) by applying graded dose of fertilizer. From the soil test values, yield and NPK uptake by the test crop, the basic parameters viz., nutrient requirement, soil efficiency and fertilizer efficiency were computed. Fertilizer adjustment equations were developed for upland rice using the basic data, which showed that N, P and K requirement to produce one quintal of rice grain was 2.75, 0.20 and 3.53 kg, respectively. Based on these equations, fertilizer recommendations were prescribed in the form of a ready reckoner for desired target yield of 30.0 and 40.0 q ha^{-1} of direct seeded rice with different combination of NPK under rainfed upland situation. Results of the verification trials proved that soil test based fertilizer prescription for direct seeded rice was economically viable in upland agro-ecosystems of Manipur.

Key words: Target yield, basic data, fertilizer prescription, upland rice

Rice (*Oryza sativa* L.) is the most important food grain crop in the north eastern hill (NEH) agro-ecosystem. It is occupying 3.5 million ha in the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, which accounts for more than 80% of the total cultivated area of the region (Baishya and Sarkar 2015). Among the rice ecosystems, direct seeded rainfed upland rice on the level terraces and on the steep slopes mainly under shifting cultivation is commonly observed. The crop under this growing condition is hardly supplied with any nutrient sources either through chemical fertilizer or organic material. This causes continuous depletion of soil fertility, which results decrease in crop yield. In the soil test crop response (STCR) correlation approach, the fertilizer doses are prescribed based on scientific fertilizer adjustment equations. The equations are developed through establishment of significant relationships between soil test values and added amount of fertilizer with the crop response in particular soil type. The fertilizer recommendations based on STCR approach are quantitative and precise, since both soil test and plant analysis are involved in it. This makes balance between applied nutrients and plant available nutrients present in soil. Besides, the STCR concept provides opportunity to the farmers to set yield target depending on their financial capacity to invest for costly fertilizers.

No such study on STCR has been carried out in NEH region particularly for direct seeded rainfed upland rice. Hence, the present experiment was undertaken with the objective to develop fertilizer adjustment equation with respect to major nutrients *viz.*, nitrogen (N), phosphorus (P) and potassium (K) for desired target yield of direct seeded rainfed upland rice.

MATERIALS AND METHODS

A field experiment was carried out in the Langol research farm of ICAR Research Complex for NEH region (24°50.379' N, 93°55.867', 817 m msl) Manipur centre with rice as the test crop. Three consecutive terraces, which were representative of typical upland rice eco-system of NEH region, were selected. Initial soil properties of those terraces were presented in Table 1. Taxonomically the soil was Typic Dystrudepts. The fertility gradient experiment was conducted adopting the inductive methodology (Ramamoorthy *et al.* 1967). The fertility gradients were created with respect to major nutrients by applying graded dose of fertilizer in the three terraces (Table 2). Unlike N and P, available K content in the terraces showed an increase with the elevation. Therefore, to obtain desired variation in available K content the upper and lower terraces were fertilized with the highest (100 kg K_2O ha^{-1}) and (0 K_2O ha^{-1}) level of K, respectively.

An exhaust crop of rice (cv. RC Maniphou 6) was grown in the kharif season of 2010 so that the fertilizers undergo transformation in the soil with plant and native soil microorganisms. After harvest of the exhaust crop each strip was divided into 21 plots. The test crop experiment was conducted in the kharif season of 2011, again, with the same crop variety *i.e.*, rice (cv. RC Maniphou 6) by superimposing 21 treatment combination consisting of three levels of N (70, 100 and 130 kg ha^{-1}), P (25, 35 and 45 kg ha^{-1}) and K (35, 50 and 65 kg ha^{-1}). In the 21 plots, all the 18 selected treatment combinations along with three controls were included in each strip adopting fractional factorial randomized block design as per the technical programme adopted by the All India Coordinated Research Project on STCR studies.

Table 2. Graded doses of fertilizers applied to the terraces

Terrace	Strip	Level of fertilizer			Fertilizer dose ($kg\ ha^{-1}$)		
					N	P	K
Upper	I	N0	P0	K2	0	0	100
Middle	II	N1*	P1*	K1*	100	35	50
Lower	III	N2	P2	K0	200	70	0

*Blanket recommendation

At harvest plot-wise grain and straw yield of rice was recorded. Soil samples were collected from a depth of 0-15 cm before the application of fertilizers and after the harvest of both gradient and test crops. The soil samples were analyzed for available N (Subbiah and Asija 1956), P (Bray and Kurtz 1945) and K (Hanway and Heidel 1952). Plant and grain samples of gradient and test crops were also collected and analyzed for N, P and K (Jackson 1973) contents and their uptake values were computed. From the soil test values, crop yield and uptake data, the basic parameters viz., like nutrient requirement (NR) for producing one quintal of rice grain, percent contribution from soil (CS) and fertilizer (CF) calculated as per the procedure given by Ramamoorthy *et al.* (1967). From the basic parameters fertilizer prescription equations were developed.

To validate target yield equations for direct seeded upland rice, 10 number of verification trials were conducted at farmers' field in different locations of Manipur state in the *kharif* seasons of 2012 and 2013 with three treatments *viz.*, farmer's practice (without fertilizers), levels of NPK for target yield of 40 q ha^{-1} and 30.0 q ha^{-1}.

RESULTS AND DISCUSSION

Expected variation in soil fertility with respect to the major nutrients N, P and K was created deliberately in three terraces. Soil test values of the strip, which was not fertilized, showed a decline of 11, 1.1 & 13 kg ha^{-1} of N, P and K, respectively (Table 3). However, in

Table 1. Some important properties of the experimental soils

Terrace	*p*H	Clay carbon	Organic	CEC	Exchangeable Al	Available K	Available N	Available P
		%		cmol(p+) kg^{-1}		kg ha^{-1}		
Upper	5.3	47.5	0.92	212	13.87	0.60	237	11.3
Middle	5.3	48.3	0.99	193	14.33	0.56	268	12.5
Lower	5.4	50.6	1.00	185	15.24	0.55	276	12.6

CEC, cation exchange capacity

Table 3. Effect of graded levels of N, P and K on soil fertility, yield and nutrient uptake by the exhaust crop

Strip	Yield ($q\ ha^{-1}$)	Nutrient uptake ($kg\ ha^{-1}$)			Available nutrient status after harvesting exhaustive crop ($kg\ ha^{-1}$)		
		N	P	K	N	P	K
I	9.6	26.2	1.5	45.2	226	10.2	235
II	27.4	70.8	4.9	108.5	285	13.5	204
III	46.2	136.4	10.3	162.3	312	13.8	172

case of the strips, which received graded level of fertilizer, showed significant increase in the status of N, P and K. Such increase in the availability of N, P and K in soil with application of graded dose of fertilizer created fertility gradient in the same location. The yield and uptake of N, P and K by the gradient crop rice increased significantly with the increase in doses of N, P and K added to various strips (Table 3).

Results showed that straw yield of the test crop rice varied from 33.8 to 75.0, 36.3 to 77.5 and 36.8 to 80.0 q ha^{-1} with mean values of 58.6, 61.3 and 63.4 q ha^{-1}; while grain yield from 9.2 to 35.8, 9.6 to 38.3 and 10.0 to 43.3 q ha^{-1} with mean values of 25.4, 26.8 and 29.1 q ha^{-1} in strip I, II and III, respectively, with different combination of NPK (Fig. 1). On average, the increases in straw yield with NPK fertilization were 74.3, 72.0 and 69.5% in strip I, II, and III, respectively, over the control; while such increases in grain yield were 191.7, 186.4 and 200.9%, respectively.

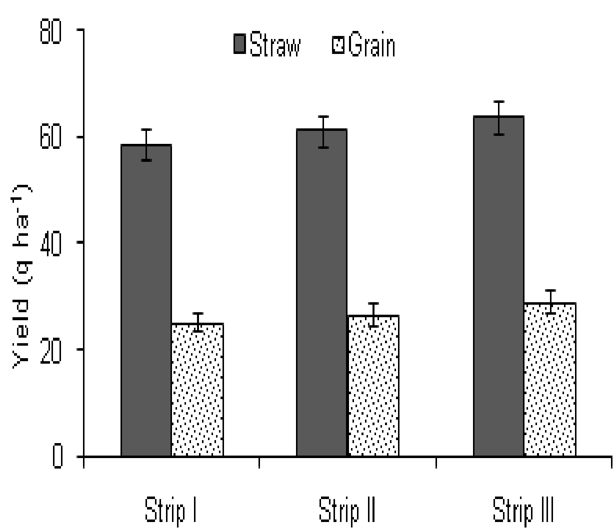

Fig 1. Average yield of rice with different combination of NPK (error bars represent the standard error of mean).

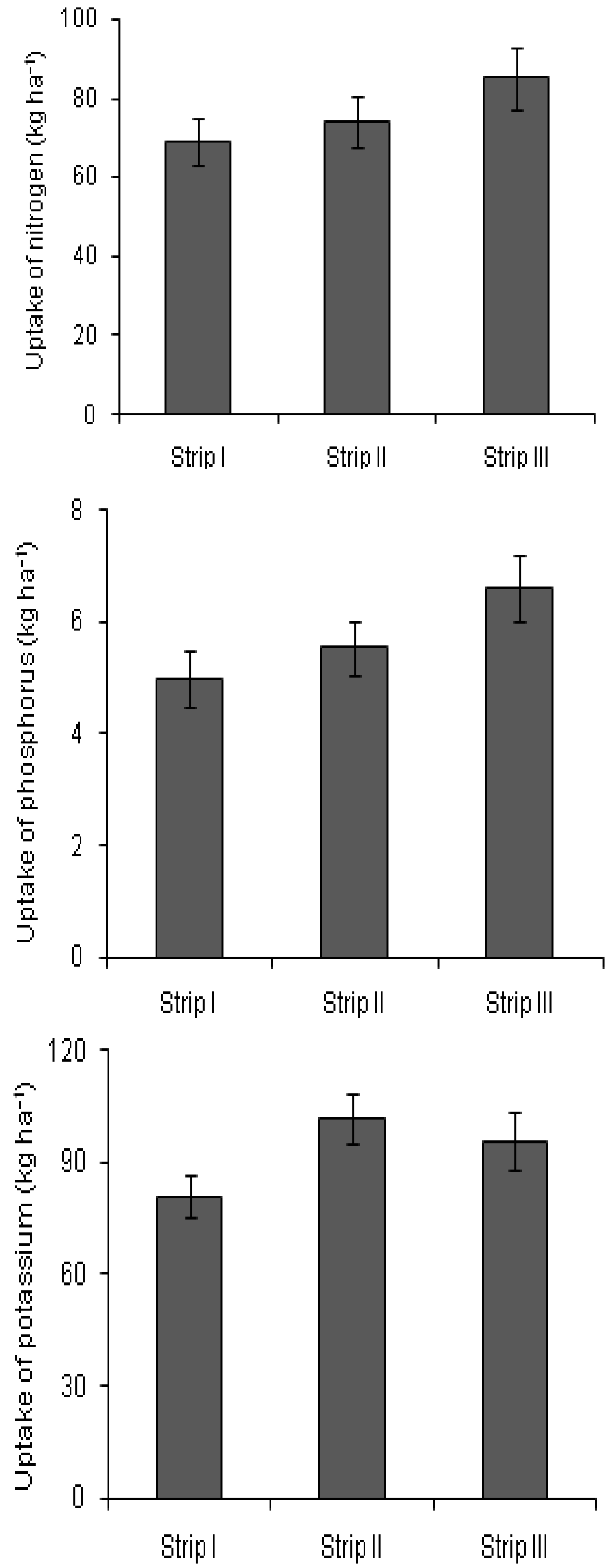

Fig 2. Average uptake of (a) nitrogen, (b) phosphorus and (c) potassium with different combination of NPK (error bars represent the standard error of mean).

Table 4. Basic parameters for upland rice under north eastern hill region

Nutrient	Basic data			Fertilizer adjustment equation
	NR (kg q-1)	CS (%)	CF (%)	
N	2.75	9.63	52.9	FN = 5.19T - 0.18SN
P	0.20	12.15	13.7	FP = 1.48T - 0.89SP
K	3.53	21.34	126.0	FK = 2.80T - 0.17SK

NR, nutrient requirement for grain production; CS, contribution from soil (soil efficiency); CF, contribution from fertilizer (fertilizer efficiency); T, yield target (q ha^{-1}); SN, SP and SK, soil available nitrogen, phosphorus and potassium (kg ha^{-1}); FN, FP and FK, fertilizer nitrogen, phosphorus and potassium required (kg ha^{-1})

Table 5. Ready reckoner of fertilizer doses at varying soil test values for specific target yield

Soil test value (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1})					
			Targeted yield 30.0 q ha^{-1}			Targeted yield 40.0 q ha^{-1}		
N	P	K	N	P	K	N	P	K
200	10	100	119	36	67	171	50	95
225	12	125	115	34	63	167	48	91
250	14	150	110	32	59	162	47	86
275	16	175	106	30	54	158	45	82
300	18	200	101	28	50	153	43	78
325	20	225	97	27	46	148	41	74
350	22	250	92	25	42	144	40	70
375	24	275	87	23	37	139	38	65
400	26	300	83	21	33	135	36	61

Table 6. Verification trails of fertilizer adjustment equations for direct seeded upland rice in Manipur

Location	Soil test value			Treatment	Fertilizer dose			Yield (q ha^{-1})	Additional yield (q ha^{-1})	% yield deviation	Net benefit (`)	Bene-fit to cost ratio
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})		N (kg ha^{-1})	P (kg ha^{-1})	K (q ha^{-1})					
Langol, Imphal	339	11	143	Farmer's practice	-	-	-	12.7	-	-	-	-
				30.0 q/ha target	95	35	61	32.5	19.8	8.3	29700	4.7
				40.0 q/ha target	146	49	88	42.2	29.5	5.5	44250	4.8
Chandanpokpi, Chandel	308	20	255	Farmer's practice	-	-	-	9.2	-	-	-	-
				30.0 q/ha target	100	27	41	29.7	20.5	-1.0	30750	5.9
				40.0 q/ha target	150	41	69	43.6	34.4	9.0	51600	6.4
Lambung, Chandel	216	23	228	Farmer's practice	-	-	-	10.5	-	-	-	-
				30.0 q/ha target	116	24	45	32.8	22.3	9.3	33450	6.1
				40.0 q/ha target	165	39	73	41.5	31	3.8	46500	5.5
Chandel Christian, Chandel	196	10	95	Farmer's practice	-	-	-	13.6	-	-	-	-
				30.0 q/ha target	120	36	70	30.6	17	2.0	25500	3.5
				40.0 q/ha target	175	50	98	38.7	25.1	-3.2	37650	3.7
Hengkot, Churachandpur	277	13	114	Farmer's practice	-	-	-	11.8	-	-	-	-
				30.0 q/ha target	105	33	65	28.9	17.1	-3.7	25650	3.9
				40.0 q/ha target	155	48	92	39.0	27.2	-2.5	40800	4.3
Langol Farm, Imphal	314	9	122	Farmer's practice	-	-	-	10.8	-	-	-	-
				30.0 q/ha target	99	37	63	30.8	20	2.7	30000	4.6
				40.0 q/ha target	151	52	91	42.1	31.3	5.3	46950	4.9
Purumchumbang, Chandel	282	12	184	Farmer's practice	-	-	-	11.2	-	-	-	-
				30.0 q/ha target	105	34	52	32.2	21	7.3	31500	5.1
				40.0 q/ha target	156	48	80	40.8	29.6	2.0	44400	4.9
Lambung, Chandel	376	14	104	Farmer's practice	-	-	-	12.3	-	-	-	-
				30.0 q/ha target	87	32	66	28.7	16.4	-4.3	24600	4.0
				40.0 q/ha target	139	47	94	38.4	26.1	-4.0	39150	4.3
Hnatham, Chandel	255	5	109	Farmer's practice	-	-	-	14.2	-	-	-	-
				30.0 q/ha target	111	40	65	32.1	17.9	7.0	26850	3.8
				40.0 q/ha target	160	55	92	42.3	28.1	5.7	42150	4.2
Hengkot, Churachandpur	408	7	83	Farmer's practice	-	-	-	11.5	-	-	-	-
				30.0 q/ha target	80	38	70	31.5	20	5.0	30000	4.7
				40.0 q/ha target	135	52	100	43.1	31.6	7.8	47400	5.0

Uptake of N by the rice crop varied from 22.5 to 113.7, 24.9 to 117.7 and 26.0 to 138.3 kg ha^{-1} with mean values of 69.0, 74.2 and 85.1 kg ha^{-1}; while uptake of P from 0.9 to 8.6, 1.4 to 9.1 and 1.7 to 10.9 kg ha^{-1} with mean values of 5.0, 5.5 and 6.6 kg ha^{-1} and K from 35.3 to 127.3, 44.6 to 146.3 and 42.4 to 153.0 kg ha^{-1} with mean values of 81.2, 102.2 and 95.9 kg ha^{-1} in strip I, II and III, respectively, with different combination of NPK (Fig. 2). The results indicated significant increases in the uptake of N, K and P with different combination of NPK over the control. On average, the increases in N uptake with NPK fertilization were 227.3, 219.0 and 219.7% in strip I, II and III, respectively, over the control; while such increase was 373.9, 292.4 and 308.8% for P and 136.4, 138.5 and 141.6% for K, respectively. These were obviously due to increase in concentration of N, P and K (data not presented) and also biomass of the crop with NPK fertilization.

The pre-sowing soil test values, crop yield and nutrient uptake by the rice crop were utilized to calculate NR, CS and CF as the basic parameters (Table 4). On average N, P and K requirement to produce one quintal of rice grain was 2.75, 0.20 and 3.53 kg, respectively. The nutrient efficiency was found to be higher in case of fertilizers than in case of soil. Similar results were also reported by Bera *et al*. (2006) for irrigated rice in the Vindhyan alluvial plain and Thilagam and Natesan (2009) for cauliflower in the Inceptisols of Tamil Nadu. Results also indicated that CF for K was more than 100% (126.0%). Basal application of K in the treated plots might have facilitated release of native soil K in plant available form, which could increase uptake of the nutrient by the crop (Ray *et al*. 2000). This might be the possible reason for obtaining higher CF value of K. Reports of higher efficiency of K fertilizer are also there for irrigated rice (Bera *et al*. 2006), wheat (Bhaduri and Gautam 2013) and radish (Batabyal *et al.* 2015).

The fertilizer adjustment equations for the N, P and K were developed using the basic data and given in Table 4. On the basis of fertilizer adjustment equations a ready reckoner for direct seeded rainfed upland rice in NEH region was developed for different soil test values and target yield of 30.0 and 40.0 q ha^{-1} for NPK fertilizer prescription (Table 5). At the soil test value of 300 kg N, 12 kg P and 200 kg K ha^{-1} the fertilizer requirement would be 101 kg N, 34 kg P and 48 kg K ha^{-1} for producing 30 q ha^{-1} of rice grain; whereas, for producing 40 q ha^{-1} of rice grain with the same soil test values requirement of those fertilizers would be 153 N, 48 P and 73 kg K ha^{-1}.

Results of the verification trials showed that there was conformity between the target and actual yield. The variations in target yields of 30.0 and 40.0 q ha^{-1} for upland rice were achieved within ±10% deviation from the expected yield target (Table 6). Similar results were also reported by Bhaduri and Gautam (2013) and Bera *et al.* (2006). Rice yield, net benefit and benefit to cost ratio were always higher in treatments where fertilizer was applied on the basis of target yield approach than that in the farmer's practice or treatment without fertilizer. Average rice yield, net benefit and benefit to cost ratio were 31.0 q ha^{-1}, 28,800 ha^{-1} and 4.6 in the case of yield target of 30.0 q ha^{-1} and 41.2 q ha^{-1}, 44,085 ha^{-1} and 4.8 in the case of yield target of 40.0 q ha^{-1}. Therefore, fertilizer recommendation for direct seeded upland rice for the target yield of 40.0 q ha^{-1} was responsive and economic.

Soil test based nutrient management for a crop should consider the specific agro-ecological characteristics of an area, cropping system and socio-economic condition of the farmers. The fertilizer adjustment equations developed for direct seeded rainfed upland rice based on the soil test values, crop yield and nutrient uptake will not only ensure sustainable crop production in north eastern hill region but also help the farmers to economic use of costly fertilizers.

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