Development of Soil Test based Fertilizer Prescription Equations under IPNS for Rice in Salt affected soils of Tamil Nadu

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Abstract

Soil Test Crop Response - Integrated Plant Nutrition System (STCR - IPNS) technology in restoring soil fertility in sodic soil was well established in this study. STCR -IPNS correlation studies were conducted with rice in black calcareous sandy clay loam (Vertic Ustropept) sodic soils of Tamil Nadu, Southern India during 2019 – 2021 and fertilizer prescription equations under Integrated Plant Nutrition System (IPNS) were developed. A ready reckoner of fertilizer doses at varying soil test values, for attaining 6 and 6.5 t ha⁻¹ target grain yield of rice has been worked out. Using these equations, test verification trials were conducted on farmer's holding in Manikandam block of Tiruchirapalli district. The per cent achievement of the targets aimed was more than 90 indicating the validity of the equations for prescribing fertilizer doses for rice under sodic soils. The STCR -IPNS treatments recorded relatively higher response ratio (RR) and benefit - cost ratio (BCR) over blanket, STCR - NPK alone treatments and farmer's practice. Post-harvest soil tests for NPK revealed that there was maintenance of soil fertility under sodic soil.

Keywords: Sodic soil, Fertilizer prescription equations, STCR-IPNS,

1. Introduction

Nearly 7.0 million ha of agricultural land is affected by varying degrees of salt problems in the country. The affected area is likely to increase in the near future due to secondary salinization in irrigation commands and lift irrigated schemes, increase in dependence of agriculture on poor quality waters in semi-arid and arid regions, sea water intrusion and brackish water aquaculture in coastal regions. By 2025 area projected under salt affected soils in India is about 13 million ha. In Tiruchirappalli district, out of the total geographical area of 4,40,412 ha, 7,362 ha are slightly salt affected (pH 8.2 to 9.0), 10,729 ha are moderately salt affected (pH 9.0 to 9.6) and 64 ha are strongly salt affected (pH >10).

Alkali or sodic soil is defined as a soil having a conductivity of the saturation extract less than 4 dS m^{-1} and an exchangeable sodium percentage greater than 15. The pH is usually between 8.5 – 10.0. Most alkali soils, particularly in the arid and semi-arid regions, contain CaCO_3 in the profile in some form and constant hydrolysis of CaCO_3 sustains the release of OH^- ions in soil solution. The OH^- ions so released result in the maintenance of higher pH in calcareous alkali soils than that in non – calcareous alkali soils. Sodic soils are inherently low in organic matter ($<0.1\%$), and available N, and are more responsive to N application. These soils are more prone to N losses due to higher N volatilization caused by high pH, further aggravating N deficiency.

Grain yield of rice in salt affected soils is much lower because of its high sensitivity to salt stress (Ajay kumar et al.2016). Rice is exceptionally sensitive to salinity and sodicity at early seedling stage (Anjali et al., 2015) and high yield losses have been observed because of high mortality and poor crop establishment. Modern high yielding varieties require considerable investment to ameliorate these soils to ensure reasonable yields, but this investment is beyond the capabilities of the resource-limited small holder farmers living off these salt affected areas. Plant mortality in sodic soils is high when young seedlings are transplanted, adversely affecting plant establishment and growth.

Among the various methods of formulating fertilizer recommendations, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve, if good cultivation package is followed (Ramamoorthy and Velayutham, 2011). In the “Inductive Approach” of STCR field experimentation, all the needed variation in soil fertility level is obtained not by selecting soils at different locations as in earlier agronomic trials, but by deliberately creating it in one and the same field experiment in order to reduce heterogeneity in the soil population (types and units) studied, management practices adopted and climatic conditions. Ramamoorthy et al., (1967) have elaborated this Inductive approach and the STCR field design. The experimental data can be used for developing fertilizer recommendations for maximum yield and profit and for desired yield targets of crops. The fertilizer prescription equations developed using this model can be applied to sodic Vertisols of all tropical regions by substituting the soil nutrient status of the particular field for rice crop. On account of the above facts, the present investigation was contemplated in rice on Vertisol under sodic soil so as to elucidate the significant relationship between soil test values and crop response to fertilizers, to develop fertilizer prescription equations under IPNS for desired yield target of rice under sodic soil.

2. Materials and methods

The field experiment was conducted in typical sodic soils of Agriculture college farm, Tiruchirapalli, Tamil Nadu, Southern India. The farm is located in the Cauvery Delta Zone of Tamil Nadu at $10^\circ 15'$ and $11^\circ 2'$ N latitude and $78^\circ 10'$ to $79^\circ 5'$ E

longitude at an altitude of 90 m above MSL. The experiment was conducted during October 2019 to March 2020. The soil of the experimental field belongs to Allathur soil series taxonomically referred as Vertic Ustropept, hyper thermic family of sodic Natrustalf exhibiting sandy loam texture, alkaline reaction (pH 9.02) and non – saline conditions (EC 1.15 dS m⁻¹) and exchangeable sodium percentage (ESP) of 51.23 (Table.1). Making use of data on the yield of paddy, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P₂O₅ and K₂O applied, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy et al. (1967). To suggest soil test based balanced fertilization for rice under sodic soil, fertilizer prescription equations under IPNS were developed for sodic Vertisols (Typic Ustropepts) of Tiruchirapalli district during 2019-2021 following the Inductive cum Targeted yield model.

Table 1. Initial soil characteristics of the experimental field

Soil pH	9.02
Soil EC (dSm ⁻¹)	1.15
Soil Texture	Sandy loam
Organic carbon (%)	0.41
Available –N (kg ha ⁻¹)	224
Available –P (kg ha ⁻¹)	22.7
Available –K (kg ha ⁻¹)	249.7
Cation Exchange Capacity (c.mol (p+) kg ⁻¹)	27.4
Exchangable Sodium (m.eq/100 g of soil)	14.45
Exchangable Sodium Percentage (ESP)	52.73

These equations were test verified with a view to demonstrate the validity of fertilizer prescription equations under IPNS developed for Rice in sodic Vertisols of Trichirapalli district by conducting verification trials in farmer's fields and to suggest the target yield that gives the highest Benefit Cost Ratio (BCR) and Response Ratio (RR) to the farmers in that region. There were eight treatments viz., T₁ - Blanket (RDF alone), T₂ - Blanket (RDF+ FYM @12.5 t ha⁻¹), T₃ - STCR-NPK alone- 5 t ha⁻¹, T₄ - STCR-NPK alone - 6 t ha⁻¹, T₅ - STCR-IPNS - 5 t ha⁻¹, T₆ - STCR-IPNS - 6 t ha⁻¹, T₇ - Farmer's Practice and T₈ - absolute control. Initial soil samples were collected and analysed for available N, P and K. Based on the initial soil test values of available N, P₂O₅, K₂O and yield targets aimed, fertilizer doses were calculated and applied for STCR treatments. For IPNS treatments, 12.5 tonnes of FYM were applied basally and fertilizer N, P₂O₅, K₂O doses were adjusted accordingly.

Plot wise grain and straw yield were recorded. Soil samples were collected and analysed for available N, P and K. The details of fertilizer doses applied, grain yield, percentage achievement and response ratio are furnished in Table.1 .Using the data on

grain yield, fertilizer doses applied and cost of fertilizer inputs and produce, the parameters viz., Response Ratio (RR) and Benefit -Cost Ratio (BCR) were worked out (Response Ratio=Response in kg ha⁻¹/Quantities of fertiliser N, P₂O₅ and K₂O applied in kg ha⁻¹ Benefit-Cost Ratio=Cost of additional seed yield over control/Cost of fertiliser N, P₂O₅ and K₂O applied). Post-harvest soil samples were also collected and analysed for available N, available P and available K.

3. Results and discussion

Response of rice to fertilizer nutrients

Response of rice to different doses of fertiliser N, P₂O₅ and K₂O was assessed. The response varied from 843 kg ha⁻¹ in FYM @ 6.25 t ha⁻¹ to 2933 kg in STCR-IPNS-6.5 t ha⁻¹. The data showed that irrespective of STCR-NPK alone or STCR-IPNS, there was a progressive increase in response from lower target to higher targets and the magnitude of response was higher under STCR-IPNS than under STCR-NPK alone treatments (Table 2).

Table 2. Response of rice as influenced by various treatments under sodic soil

Treatments		Fertiliser doses (kg ha ⁻¹)			Mean grain Yield (kg ha ⁻¹)	Response (kg ha ⁻¹)
		FN	FP ₂ O ₅	FK ₂ O		
1	STCR- NPK alone – 5.5 t ha ⁻¹	144	63	73	4878	2245
2	STCR- NPK alone – 6.0 t ha ⁻¹	170	72	75**	5123	2490
3	STCR - NPK alone – 6.5 t ha ⁻¹	197	75**	75**	5390	2757
4	STCR - IPNS – 5.5 t ha ⁻¹	116	45	25*	5144	2511
5	STCR - IPNS – 6.0 t ha ⁻¹	143	54	35	5371	2738
6	STCR – IPNS – 6.5 t ha ⁻¹	170	64	49	5566	2933
7	FYM alone @ 6.25 t ha ⁻¹	23	10	21	3476	843
8	FYM alone @ 12.5 t ha ⁻¹	46	19	42	3987	1354
9	Absolute control	0	0	0	2633	0

*maintenance dose

** maximum dose

Basic parameters

Using the data on the grain yield, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P₂O₅, K₂O and FYM applied, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were computed (Table 3).

Table 3. Basic parameters

Parameters	Basic data		
	N	P ₂ O ₅	K ₂ O
Nutrient requirement (kg q ⁻¹)	1.44	0.29	1.76
Per cent contribution from soil (Cs)	17.18	28.14	23.42
Per cent contribution from fertilizers (Cf)	23.71	18.2	59.4
Per cent contribution from FYM (Cfym)	18.89	12.56	43.59

This formed the basis to compute the basic parameters and develop the fertilizer prescription equations under IPNS for rice under sodic soil. The results emanated from the present investigation revealed that rice requires 1.44 kg N, 0.29 kg P₂O₅ and 1.76 kg K₂O for producing one quintal of grain yield.

The per cent contribution of N from soil was 17.18 and fertilizer was 23.71. With regard to P₂O₅, the percent contribution from soil was 28.14 and fertilizer was 18.2 while for K₂O, the percent contribution from soil was 23.42 and from fertilizer was 59.4 percent. The percent contribution of nutrients from FYM was 18.89, 12.56 and 43.59 per cent N, P₂O₅ and K₂O respectively.

Fertilizer Prescription Equations for rice under sodic soils

Making use of the basic parameters viz., NR, Cs, Cf and Cfym, the Fertiliser Prescription Equations were developed under NPK alone and IPNS.

STCR-NPK alone	STCR-IPNS (NPK+FYM)
FN = 6.08 T - 0.72 SN	FN = 6.08 T - 0.72 SN - 0.80 ON
FP ₂ O ₅ = 1.64 T - 1.55 SP	FP ₂ O ₅ = 1.64 T - 1.55 SP - 0.69 OP
FK ₂ O = 2.96 T - 0.39 SK	FK ₂ O = 2.96 T - 0.39 SK - 0.73 OK

where, FN, FP₂O₅ and FK₂O are fertilizer N, P₂O₅ and K₂O in kg ha⁻¹, respectively; T is the grain yield target in q ha⁻¹ and SN, SP and SK respectively are alkaline KMnO₄-N, Olsen-P and NH₄OAc -K in kg ha⁻¹; ON, OP and OK are quantities of N, P and K in Kg ha⁻¹ supplied through FYM.

Soil test based fertilizer recommendations for various yield targets of rice under sodic soil

Ready reckoner of fertilizer doses (nomograms) were formulated for desired yield targets of rice for a range of soil test values under IPNS (NPK plus FYM @ 12.5 t ha⁻¹). Using the fertilizer prescription equations under IPNS, the extent of saving of inorganic fertilizers was computed. The results showed that with the application of FYM @ 12.5 t ha⁻¹ (with 30 % moisture, 0.60 %, 0.30 % and 0.5 % NPK respectively), there was a saving of 42, 18 and 32 kg of fertilizer N, P₂O₅ and K₂O respectively.

A perusal of the estimate showed that when NPK alone were applied, for a soil test value of 180 kg KMnO₄-N ha⁻¹, the doses of fertilizer N required for desired yield targets of 5.5, 6.0 and 6.5 t ha⁻¹ were 204, 235 and 265 kg ha⁻¹, respectively. When FYM @ 12.5 t ha⁻¹ was applied along with NPK, the required fertilizer N doses were 162, 193 and 223 kg ha⁻¹ with 20.58, 17.87 and 15.84 per cent reduction in fertilizer doses over NPK alone respectively for the same yield target and soil test values. In case of P fertilization, when NPK alone were applied, for a soil test value of 18 kg ha⁻¹ of Olsen-P, the doses of fertilizer P₂O₅ required for desired yield targets of 5.5, 6.0 and 6.5 t ha⁻¹ were 62, 70 and 78 kg ha⁻¹ respectively. When NPK were applied along with FYM @ 12.5 t ha⁻¹, the doses were 44, 52 and 60 kg ha⁻¹ with a per cent reduction of 29.03, 25.71 and 23.07 respectively over NPK alone (Bagavathi Ammal et al. (2013)). With regard to fertilizer K₂O doses, it was found that to achieve the desired yield targets of 5.5, 6.0 and 6.5 t ha⁻¹, for a soil test value of 200 kg NH₄OAc-K, the fertilizer K₂O requirements were 84, 99 and 114 kg ha⁻¹, respectively. When NPK were applied with FYM @ 12.5 t ha⁻¹, the K₂O doses were 52, 67 and 82 kg ha⁻¹ with a percent reduction of 38.09, 32.32 and 28.07 over NPK alone respectively (Table 4).

Table 4. Soil test based fertilizer recommendations for various yield targets of rice under sodic soil

Soil test values (kg ha ⁻¹)			NPK alone									NPK +FYM @ 12.5 t ha ⁻¹								
			5.5 (t ha ⁻¹)			6.0 (t ha ⁻¹)			6.5 (t ha ⁻¹)			5.5 (t ha ⁻¹)			6.0 (t ha ⁻¹)			6.5 (t ha ⁻¹)		
SN	SP	SK	FN	FP ₂ O ₅	FK ₂ O	FN	FP ₂ O ₅	FK ₂ O	FN	FP ₂ O ₅	FK ₂ O	FN	FP ₂ O ₅	FK ₂ O	FN	FP ₂ O ₅	FK ₂ O	FN	FP ₂ O ₅	FK ₂ O
180	18	200	204	62	84	235	70	99	265	78	114	162	44	52	193	52	67	223	60	75**
220	22	240	176	56	69	206	64	84	236	72	98	134	38	37	164	46	52	194	54	66
240	24	260	161	53	61	192	61	76	222	69	91	119	35	29	150	43	44	180	51	59
260	26	280	147	49	53	177	58	68	208	66	83	105	31	25*	135	40	36	166	48	51

NB: * maintenance dose. **maximum dose

Blanket dose: 187.5 : 50 : 50 kg ha⁻¹ of fertilizer N, P₂O₅ & K₂O respectively for rice

Note: When FYM@ 12.5t ha⁻¹ with 0.6, 0.30, 0.5 and 30 % of moisture, N, P and K, respectively is applied 42,18 and 32 kg of N, P₂O₅ and K₂O ha⁻¹ could be reduced from the recommended dose of fertilizer; 12 kg ha⁻¹ of fertilizer N could be reduced when Azospirillum is applied @ 2 kg ha⁻¹; when FYM and Azospirillum are applied jointly, 52;16 and 27 kg ha⁻¹ of N, P₂O₅ and K₂O could be reduced from the recommended dose of fertilizers.

Test verification trials under farmers' holdings

Grain yield of Rice

The mean grain yield of rice recorded at the three locations are furnished in Table 5. In all the locations, the highest grain yield was recorded with STCR-IPNS-6 t ha⁻¹ (5.54 t ha⁻¹) followed by STCR-IPNS-5 t ha⁻¹ (4.69 t ha⁻¹). The highest response ratio was recorded in STCR-IPNS-6 t ha⁻¹ (7.47 kg kg⁻¹) followed by STCR-IPNS-5 t ha⁻¹ (7.11 kg kg⁻¹). The highest B: C ratio was recorded in STCR-IPNS-6 t ha⁻¹ (1.86). The increase of yield in STCR-IPNS-6 t ha⁻¹ was 24.7 per cent over blanket (RDF alone), 21.7 per cent over blanket + FYM and 41.7 per cent over farmers practice. The grain yields recorded under STCR treatments were significantly higher than that under blanket and farmer's practice. The grain yields ranged from 3910 kg ha⁻¹ in farmer's practice to 5540 kg ha⁻¹ in STCR-IPNS 6 t ha⁻¹. The increase of yield in STCR-IPNS-6 t ha⁻¹ was 24.7 per cent over blanket (RDF alone), 21.7 per cent over blanket + FYM and 41.7 per cent over farmers practice. The results revealed that the targeted yield has been achieved within +/- 10 per cent variation proving the validity of the equations. The favorable influence of organics, inorganics and biofertilizers on chemical, physical and biological properties of soils under IPNS would have resulted in such higher grain yields of rice (Dey, 2016).). The NPK uptake also followed the same trend as that of grain yield.

Table 5. Effect of soil test based fertilization under IPNS for Rice under sodic soil (Mean of three villages)

Treatments	Fertilizer doses (kg ha ⁻¹)			Grain yield (t ha ⁻¹)	Percent Achieve ment	RR (kg kg ⁻¹)	B:C ratio
	N	P ₂ O ₅	K ₂ O				
T ₁ - RDF alone	188	50	50	4.44	-	74 ^{6.}	1.61
T ₂ - RDF +FYM @12.5 t ha ⁻¹	188	50	50	4.55	-	12 ^{7.}	1.68
T ₃ -STCR-NPK alone 5 t ha ⁻¹	209	45	54	4.65	93.0	98 ^{6.}	1.70
T ₄ STCR-NPK alone 6 t ha ⁻¹	270	62	75*	5.49	91.5	35 ^{7.}	1.73
T ₅ - STCR-IPNS-5 t ha ⁻¹	167	27	25*	4.69	93.8	11 ^{7.}	1.83
T ₆ - STCR-IPNS-6 t ha ⁻¹ *	228	44	49	5.54	92.3	47 ^{7.}	1.86
T ₇ - Farmers practice	160	35	40	3.91	-	00 ^{6.}	1.41
T ₈ - Absolute Control	0	0	0	2.50	-	-	1.09

STCR-IPNS : NPK+12.5 t FYM ha⁻¹ ; * Maintenance dose

Per cent achievement

The highest per cent achievement of the yield targets aimed at were recorded with targeting for 6 t ha⁻¹ grain yield. Yield targeting with STCR -IPNS recorded relatively higher per cent achievement than that aimed under NPK alone. The per cent achievement of the targets aimed was more than 90 for 6t ha⁻¹ yield target under NPK alone and STCR -IPNS indicating the validity of the equations for prescribing fertilizer doses for rice under sodic soil.

Response ratio (RR)

The mean RR recorded for various treatments ranged from 6.0 in farmer's practice to 7.47 in 6 t ha⁻¹ – STCR -IPNS. Among the two targets tried, targeting for 6 t ha⁻¹ recorded relatively higher RR than with 5 t ha⁻¹ and it has recorded significantly higher yields. This might be due to the better use efficiency of applied NPK fertilizers at high yield target levels. Likewise, STCR - IPNS treatments recorded higher RR when compared to their respective NPK alone treatments. Blanket recorded 6.74 RR which is lower than STCR treatments. The relatively higher RR recorded under STCR and IPNS treatments when compared to blanket, might be due to balanced supply of nutrients from fertilizer, efficient utilization of applied fertilizer nutrients in the presence of organic sources and the synergistic effect of the conjoint addition of various sources of nutrients (Rao and Srivastava 2000).

Benefit - Cost Ratio (BCR)

The mean BCR ranged from 1.41 in farmer's practice to 1.86 in 6 t ha⁻¹ –STCR IPNS and the trend of results were similar as that of RR. Among the targets aimed, 6 t ha⁻¹ recorded higher BCR over 5 t ha⁻¹. When NPK alone and STCR - IPNS were compared, STCR -IPNS treatments recorded higher BCR (Table 1). In STCR- IPNS technology, the amounts of fertilizer nutrients that are to be applied to obtain any pre-set yield levels are adjusted for the amount of nutrients present in the soil and organic / bio-fertilizers. On account of this adjustment, there is a reduction in the quantity of the nutrients that are to be supplied through fertilizers (Coumaravel, 2012).

Post-harvest soil fertility

The data on KMnO₄-N, Olsen-P and NH₄OAc-K indicated the build up and maintenance of soil fertility due to soil test based fertilizer recommendation under IPNS. Despite higher removal of nutrients, the fertility status " was maintained at higher level in IPNS as compared to NPK alone. This might be attributed to the prevention of losses of nutrients under IPNS, even after meeting the crop needs. The findings of Velayutham et al (2016) support the results recorded in the present study. It is concluded that for obtaining aimed yield targets and profits with sustenance of soil fertility in Vertisols, soil test based fertilizer recommendation under IPNS could be followed for rice under salt affected soils.

Summary and conclusion

It is concluded that for obtaining aimed yield targets and profits with sustenance of soil fertility in salt affected soils, soil test based fertilizer recommendation under IPNS could be followed for rice with suitable reclamation practices. Using the fertilizer prescription equations under IPNS, the extent of saving of inorganic fertilizers was found. i.e with the application of FYM @ 12.5 t ha^{-1} (with 30 % moisture, 0.60 %, 0.30 % and 0.5 % NPK respectively), there was a saving of 42, 18 and 32 kg of fertilizer N, P_2O_5 and K_2O respectively.

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