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Impact of Different Approaches of Nutrient Recommendations for Aerobic Rice on Soil Fertility of *Alfisols* of Eastern Dry Zone of Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment to study the impact of different approaches of nutrient recommendations for aerobic on soil fertility of *Alfisols* of Eastern Dry Zone of Karnataka was conducted during Kharif 2020 at Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru. The experiment was laid out in RCBD comprising twelve treatments replicated thrice. The results revealed that significantly higher grain yield (68.85 q ha^{-1}) was recorded in treatment receiving fertilizer nutrients based on Soil Test Crop Response (STCR) inorganic approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values which was superior compared to Low-Medium-High (LMH) approach and Blanket recommendation The higher post- harvest soil available nutrient status was registered in STCR integrated approach based on predicted soil test values compared to package of practice and LMH approach.

Keywords: Aerobic rice; targeted yield; soil properties; STCR approach.

1. INTRODUCTION

The food security in Asia is challenged by increasing food demand and is threatened by declining availability of water with growing population, increased urbanisation and environmental degradation. In India, rice occupies an area of 43.79 million hectare with

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production of 112.91 million tonnes with an average productivity of 2578 kg per hectare. In Karnataka, rice is being grown in an area of 1.32 m ha with an annual production of 4.24 m t and productivity is 3338 kg ha^{-1} (2019) [1]. With emerging water scarcity in many parts of the world, the traditional way of lowland rice cultivation can no longer be sustained and traditional system of rice production in long run leads to destruction of soil aggregates and reduction in macropore volumes [2]. Therefore, alternatives to the conventional flooded rice cultivation were developed worldwide to reduce water consumption and to produce more rice with less water. Among the different water saving strategies, "aerobic rice" is considered a promising cultivation system for water scarce areas.

Aerobic rice is broadly defined as "a production system in which, direct seeding of high yielding and input responsive rice cultivars with aerobic adaptation grown in non-puddle, non-flooded and non-saturated soil during the entire growing period" [3]. It is a new concept in which rice is grown like an upland crop with high inputs and supplementary irrigations, when rainfall is insufficient. Although India has made considerable advances in agricultural research, still the blanket recommendation of cultivation practices for adoption over larger areas are in vogue.

The current energy crisis prevailing, higher prices and lack of proper supply system of fertilizers, deterioration of soil fertility calls for more effective nutrient management practices using manure and fertilizers judiciously to sustain yield levels [4]. The effective nutrient management involves site specific nutrient recommendations that include timely and balanced fertilizer nutrient application, using appropriate methods and practicing integrated plant nutrient supply system using chemical fertilizers, organic manures, crop residues and biofertilizers.

Considering high cost of fertilizers and their adverse environmental implications, fertilizer recommendations based on soil test values, residual effect and yield targets becomes highly important. This can be achieved by following targeted yield approach involving integrated plant nutrition system (IPNS) for enhancing crop productivity, nutrient use efficiency as well as soil nutrient balance [5].

2. MATERIALS AND METHODS

The field experiment was conducted on aerobic rice during 2020-21 at Zonal Agricultural research station, University of Agricultural Sciences, GKVK, Bangalore (13° 04' 55.2" N latitude, 77° 34' 10.0" E longitude). The experimental soil was sandy loam in texture belonging to vijayapura series of great group *Kandic paleustalfs* and had pH of 5.77, electrical conductivity 0.085 dS m^{-1} (1: 2.5 soil : water ratio) and organic carbon 4.44 g kg^{-1}. Treatments schedule for aerobic rice comprising of T_1: STCR through inorganics (65 q ha^{-1}) - Actual STV* (*Soil Test Value), T_2: STCR through inorganics (65 q ha^{-1}) - Predicted STV, T_3: STCR through integrated (65 q ha^{-1}) - Actual STV, T_4: STCR through integrated (65 q ha^{-1}) - Predicted STV, T_5: STCR through inorganics (55 q ha^{-1}) - Actual STV, T_6: STCR through inorganics (55 q ha^{-1}) - Predicted STV, T_7: STCR through integrated (55 q ha^{-1}) - Actual STV, T_8: STCR through integrated (55 q ha^{-1}) - Predicted STV, T_9: Package of practice, T_{10}: LMH (STL) - Actual STV, T_{11}: LMH (STL) - Predicted STV and T_{12}: Absolute control.

The following STCR fertilizer adjustment equation and post harvest soil test value prediction equations developed by AICRP on STCR, University of Agricultural Sciences (UAS), Bengaluru centre under *Alfisols* of Eastern Dry Zone of Karnataka was used for STCR treatments and to predicted the post harvest soil test value for the preceding crop of aerobic rice (dry chilli) which can be used as initial soil test value for the present investigation to prescribe the fertilizer dose. More details are regarding development of targeted yield equations and post harvest soil test value prediction equations are provided in Ph.D. thesis on "Development of targeted yield equation for aerobic rice and its evaluation on *Alfisols* of Eastern dry zone of Karnataka" [6] at the same experimental site. The quantity of fertilizer nutrients (NPK) applied for each treatment is mentioned in Table 2.

There were twelve treatments replicated three times in a randomized complete block design (RCBD). Aerobic rice seeds (Var. MAS 946-1) were sowed in rows at proper spacing in the first week of July 2020, after basal application of fertilizers as per treatments. The remaining half dose of N was top-dressed in two splits at tillering stage and boot stage. The crop was cultivated adopting proper package of practices. All climatic conditions were favourable for growth

Table 1. Post harvest soil test value prediction equation

Prediction equation	R^2 value
Inorganic approach	
PHN = 188.752 + 0.001** SN + 0.203 FN - 0.184 UN	0.610**
PHP = - 6.133 + 1.089** SP + 1.188** FP - 1.299* UP	0.965**
PHK = 5.075 + 1.138** SK + 1.275** FK - 0.249 UK	0.925**
IPNS approach	
PHN = 191.090** - 0.003 SN + 0.087** FP - 0.008 UN	0.442**
PHP = 7.325 + 0.721** SP + 1.167** FP + 2.515** UP	0.890**

STCR- Inorganics (NPK alone) equation	*STCR- IPNS (Integrated plant nutrient supply) equation*
F.N. = 3.02879 T – 0.20314 STV-N	*F.N. = 2.89282 T – 0.20320 STV - N – 0.72978 OM*
F.P_2O_5. = 1.24589 T – 0.07368 STV - P_2O_5	*F.P_2O_5.= 1.13206 T – 0.06960 STV - P_2O_5 – 0.48911 OM*
F.K_2O. = 1.51168 T – 0.22617 STV-K_2O	*F.K_2O. = 1.50402 T – 0.21105 STV - K_2O – 0.42410 OM*

Table 2. Quantity of fertilizer nutrients and poultry manure applied through different approaches as per the treatments and soil test values

Treatments	Soil test values			Poultry manure applied	Fertilizer nutrients applied		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
	kg ha^{-1}			t ha^{-1}	kg ha^{-1}		
T_1	260.59	101.05	271.64	0	143.94	73.54	36.82
T_2	207.10	174.48	298.07	0	154.80	68.13	30.84
T_3	261.67	106.92	305.92	10	127.56	61.25	28.96
T_4	205.62	167.75	456.03	10	138.95	57.08	2.12
T_5	260.21	99.88	221.67	0	113.72	61.16	33.01
T_6	202.89	149.36	276.69	0	125.37	56.85	20.56
T_7	262.08	93.65	245.75	10	98.55	50.85	26.62
T_8	201.60	145.27	340.47	10	110.84	47.26	6.62
T_9	272.53	115.60	286.76	10	100.00	50.00	50.00
T_{10}	266.56	98.55	285.69	10	125.00	37.50	50.00
T_{11}	204.08	165.92	322.27	10	125.00	37.50	45.83
T_{12}	243.41	56.96	168.13	0	0.00	0.00	0.00

*T_1: STCR through inorganics (65 q ha^{-1}) - Actual STV**	*T_7: STCR through integrated (55 q ha^{-1}) - Actual STV*
T_2: STCR through inorganics (65 q ha^{-1}) - Predicted STV	*T_8: STCR through integrated (55 q ha^{-1}) - Predicted STV*
T_3: STCR through integrated (65 q ha^{-1}) - Actual STV	*T_9: Package of practice, T_{10}: LMH (STL) - Actual STV*
T_4: STCR through integrated (65 q ha^{-1}) - Predicted STV	*T_{10}: LMH (STL) - Actual STV*
T_5: STCR through inorganics (55 q ha^{-1}) - Actual STV	*T_{11}: LMH (STL) - Predicted STV*
T_6: STCR through inorganics (55 q ha^{-1}) - Predicted STV	*T_{12}: Absolute control*

and development of the crop. The soil samples were collected before sowing and after the harvest at 0-15 cm soil depth. Basic soil parameters were estimated by using standard laboratory procedures outlined by Jackson [7] and nutrient balance was worked out.

3. RESULTS AND DISCUSSION

3.1 Grain yield of Aerobic Rice

Significantly higher grain yield (Table 3) of 68.85 q ha^{-1} was recorded with the application of nutrients based on STCR approach for the targeted yield of 65 q ha^{-1} through inorganic based on predicted soil test values (T_2) compared to treatment T_8 (60.14 q ha^{-1}) [STCR integrated (55 q ha^{-1}) - Predicted STV], T_7 (57.55 q ha^{-1}) [STCR integrated (55 q ha^{-1}) - Actual STV], T_9 (53.25 q ha^{-1}) (Package of practice), T_{11} (49.15 q ha^{-1}) (LMH - predicted STV), T_{10} (48.76 q ha^{-1}) (LMH - Actual STV), and T_{12} (20.66 q ha^{-1}) (Absolute control). However, it was on par with treatments receiving fertilizers through STCR inorganic approach for the targeted yield of 65 q ha^{-1} based on actual soil test values (T_1: 65.50 q ha^{-1}); STCR integrated approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values (T_4: 63.79 q ha^{-1}) and actual test values (T_3: 61.70 q ha^{-1}); STCR inorganic approach for the targeted yield of 55 q ha^{-1} for predicted soil test values (T_6: 62.96 q ha^{-1}) and actual soil test values (T_5: 61.58 q ha^{-1}). The higher yield in STCR treatments could be attributed to the ability of targeted yield approaches to satisfy the nutrient demand of crop more efficiently. These findings are in close accordance with those reported by Kumar and Paramananda, 2018 [8] who opined that application of fertilizers based on STCR approach at critical physiological phases would have supported for better assimilation of photosynthates towards grain.

3.2 Soil pH

After harvesting rice crop, the soil pH was increased compared to the respective initial soil pH but, no significant difference was found with respect to post harvest soil pH among the treatments (Table 3). However, numerically higher pH value (6.02) was recorded in absolute control where no fertilizers were applied (T_{12}) while the lower pH value (5.55) was found in STCR inorganic approach for the targeted yield of 55 q ha^{-1} using actual soil test values (T_5). The soil pH was higher in integrated approach irrespective of target and actual or predicted soil test values compared to inorganics which might be attributed to release of basic cations from poultry manure during its decomposition and source of phosphatic fertilizer used was single super phosphate which contains calcium, which neutralizes soil acidity to some extent [9,10].

3.3 Soil EC

The data clearly indicated that EC values of post harvest soil in all the treatments increased compared to the respective initial treatments. Similarly, the electrical conductivity (EC) values of the post-harvest soil indicated a slight increase in all the treatments as compared to control (0.081 dS m^{-1}) (Table 3). The significantly higher EC (0.104 dS m^{-1}) was found where fertilizers were applied through STCR approach for a targeted yield of 55 q ha^{-1} through inorganics (T_6) based on predicted soil test values compared to control (T_{12}: 0.081) and the remaining treatments were on par. The results indicates that the EC was higher where fertilizers were applied based on predicted soil test values and application of poultry manure in integrated approach. The increase in soil EC after harvest of aerobic rice in STCR inorganic and integrated approach through predicted soil test values may be due to release of soluble salts from poultry manure upon decomposition in integrated approach and direct application of slightly higher dose of inorganic fertilizers with predicted soil test value that might have caused higher EC values [11].

3.4 Soil Organic Carbon

The organic carbon content of the post-harvest soil was increased compared to initial and it was found non-significant among the different treatments (Table 3). However, numerically higher organic carbon content (0.52 %) was recorded in STCR target of 65 q ha^{-1} integrated approach with PM (T_4) based on predicted soil test values, which was on par with LMH approach with predicted soil test value based fertilizer dose whereas, lower value (0.44 %) was recorded in STCR target 55 q ha^{-1} through inorganics for actual soil test values (T_5). The organic carbon content was found higher in STCR integrated treatments, LMH and RDF approach compared to STCR inorganic approach due to application of poultry manure at 10 t ha^{-1} in these treatments. This was mainly due to application of poultry manure at the rate of 10 t ha^{-1} and root biomass of rice crop upon gradual decomposition substantially contributed to pool of soil organic carbon in contrast to STCR inorganic treatments where no poultry manure was added [12]. These increase/ maintenance in organic carbon content due to use of fertilizers can be attributed to contribution of biomass to the soil in the form of crop stubbles and residues.

3.5 Available Nitrogen

Significantly higher (280.37 kg ha^{-1}) available nitrogen was recorded in STCR integrated approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values (T_4) compared to absolute control (T_{12}) where the available nitrogen was 239.12 kg ha^{-1}, but it was found to be on par with all the remaining treatments. Soil available nitrogen after harvest of aerobic rice was improved in all the treatments of fertilizer nutrient application (both integrated and inorganic approach) except in absolute control (T_{12}) where soil available nitrogen was reduced over its initial content (Table 4). The improved available nitrogen after harvest of rice crop was mainly due to mineralization of applied poultry manure along with direct addition of inorganic nitrogen fertilizers which contributed to the pool of available nitrogen and might have improved water and nutrient holding capacity in integrated approach in contrast with other STCR inorganic treatments [13].

Table 3. Influence of different approaches of nutrient application on yield and physico - chemical properties of post harvest soil of aerobic rice

Treatment details	Grain yield	Soil pH (1:2.5)		EC (dS m^{-1})		Organic Carbon (%)	
	q ha^{-1}	Initial	After harvest	Initial	After harvest	Initial	After harvest
T_1	65.50	5.75	5.76	0.070	0.087	0.42	0.45
T_2	68.85	5.45	5.78	0.088	0.090	0.46	0.48
T_3	61.70	5.93	5.81	0.089	0.099	0.46	0.50
T_4	63.79	5.85	5.91	0.090	0.100	0.49	0.52
T_5	61.58	5.54	5.55	0.087	0.102	0.38	0.44
T_6	62.96	5.45	5.71	0.088	0.104	0.45	0.45
T_7	57.55	5.84	5.86	0.087	0.101	0.36	0.50
T_8	60.14	5.81	5.98	0.088	0.103	0.43	0.51
T_9	53.25	5.76	5.88	0.085	0.096	0.48	0.51
T_{10}	48.76	5.75	5.83	0.091	0.095	0.50	0.51
T_{11}	49.15	5.82	5.84	0.093	0.100	0.50	0.52
T_{12}	20.66	5.98	6.02	0.071	0.081	0.45	0.49
S.Em. ±	**2.88**	**-**	**0.09**	**-**	**0.006**	**-**	**0.03**
C.D. @ 5 %	**8.39**	**-**	**NS**	**-**	**0.018**	**-**	**NS**

NS: Non significant

3.6 Available P_2O_5

Available P_2O_5 decreased from the initial level in all the treatments except control and all the STCR treatments of 55 q ha^{-1} where slightly increased (Table 4). Significantly higher (109.34 kg P_2O_5 ha^{-1}) value was found in STCR yield target 65 q ha^{-1} through inorganics based on predicted soil test values (T_2) compared to LMH approach where nutrients were applied based on predicted (T_{11}: 93.74 kg P_2O_5 ha^{-1}) and actual (T_{10}: 88.61 kg P_2O_5 ha^{-1}) soil test values and with control plots (T_{12}: 57.51 kg P_2O_5 ha^{-1}) where no fertilizers and manure was applied. Interestingly, no significant difference was noticed among actual and predicted soil test value based fertilizer recommendation under STCR inorganic and integrated approach at both the targets and LMH approach. The significantly higher available phosphorus in STCR inorganic approach compared to integrated approach could be attributed to application of lower dose of inorganic fertilizers and lower initial available phosphorus content in soil. However no significant difference was observed between inorganic and integrated approach. The soils on which the present study was conducted are acidic in reaction (pH 5.77) where Al and Fe ion concentrations may be higher hence, the response to phosphatic fertilizer was high and had higher available phosphorus content in soil. These results are in conformity with findings of Ashwini [14].

3.7 Available K_2O

Application of nutrient doses as per STCR integrated approach (T_4) for the targeted yield of 65 q ha^{-1} based on predicted soil test values recorded significantly higher available potassium content (297.52 kg ha^{-1}) (Table 4) in soil after harvest of aerobic rice compared to treatment T_2 [STCR inorganics (65 q ha^{-1}) - Predicted STV] (229.08), T_6 [STCR inorganics (55 q ha^{-1}) - Predicted STV] (222. 40 kg ha^{-1}), T_7 [STCR integrated (55 q ha^{-1}) - Actual STV] (221.88 kg ha^{-1}), T_1 [STCR inorganics (65 q ha^{-1}) - Actual STV] (217.36 kg ha^{-1}), T_5 [STCR inorganics (55 q ha^{-1}) - Actual STV] (216.60 kg ha^{-1}) and T_{12} (Absolute control) (166.20 kg ha^{-1}). In all the treatments of different fertilizer nutrient recommendations available potassium content after harvest of the crop was found to be reduced. Higher available potassium in T_4 treatment even without application of potassium fertilizer might be due to higher potassium content in native soil (316. 49 kg ha^{-1}) and also contribution to the pool of available potassium in soil through mineralization of applied poultry manure [15].

Table 4. Influence of difference approaches of fertilizer recommendations on available major nutrients status of post harvest soil of aerobic rice

Treatments	Avail. N		Avail. P_2O_5		Avail. K_2O	
	Kkg ha^{-1}					
	Initial	After harvest	Initial	After harvest	Initial	After harvest
T_1	260.59	261.33	101.05	100.81	271.64	217.36
T_2	257.23	264.69	115.46	109.34	282.56	229.08
T_3	261.67	267.09	106.92	99.18	305.92	291.20
T_4	260.32	280.37	113.47	104.30	316.49	297.52
T_5	260.21	265.07	99.88	103.24	221.67	216.60
T_6	261.33	266.20	102.87	105.43	229.44	222.40
T_7	262.08	266.93	93.65	101.47	245.75	221.88
T_8	260.96	277.39	100.36	103.32	261.11	249.44
T_9	268.05	268.61	115.60	102.21	286.77	274.30
T_{10}	266.56	268.95	98.55	88.61	285.69	283.72
T_{11}	269.17	272.16	111.52	93.74	289.36	289.04
T_{12}	243.41	239.12	56.96	57.51	168.13	166.20
S.Em. ±	**-**	**9.59**	**-**	**3.53**	**-**	**18.14**
C.D. @ 5 %	**-**	**28.12**	**-**	**10.35**	**-**	**53.19**

3.8 Available Sulphur

Significantly higher available sulphur content (35.00 mg kg^{-1}) was recorded in T_8 [STCR integrated (55 q ha^{-1}) - Predicted STV] as compared to STCR target of 65 q ha^{-1}through inorganic approach using actual soil test values (27.75 mg kg^{-1}) (T_1) Table 5).. However, it was found to be on par with all the treatments except in T_{12} (Absolute control). The sulphur content was higher where poultry manure was applied along with inorganic fertilizers compared to inorganic fertilizers alone. Application of phosphorus through SSP which contain 11 per cent sulphur and mineralization of added poultry manure, which substantially contributed to plant available sulphur. These results are in accordance with Chandrakanth [16].

3.9 Exchangeable Calcium

Significant difference in exchangeable calcium was found between treatments due to different approaches of nutrient recommendations through actual and predicted soil test values (Table 5). Significantly higher [3.33 c mol (p^+) kg^{-1}] exchangeable calcium was recorded in STCR targeted yield of 55 q ha^{-1} through integrated approach (T_8) where nutrients were applied using predicted soil test values and lower exchangeable calcium was recorded in absolute control [T_{12}: 2.29 c mol (p^+) kg^{-1}]. Exchangeable Ca content in soil was decreased from its corresponding initial content after harvest of aerobic rice crop in all the approaches of fertilizer nutrient recommendations including in absolute control due to crop removal. Among inorganic and integrated approach higher calcium content was recorded in integrated approach due to addition of some amount of secondary nutrients from the straight fertilizes particularly SSP which contains 18 per cent of Ca which might have resulted in increase in calcium content and also release of Ca during mineralization of added poultry manure [15].

3.10 Exchangeable Magnesium

Perusal of data from Table 5 reveals that there was no significant difference among the treatments with respect to exchangeable magnesium content in post-harvest soils of aerobic rice crop. However, numerically higher value [1.18 c mol (p^+) kg^{-1}] was recorded where fertilizer nutrients were applied through STCR integrated approach based on predicted soil test values for the targeted yield of 65 q ha^{-1} (T_4) and the lower value [1.00 c mol (p^+) kg^{-1}] was recorded in absolute control (T_{12}) where no fertilizers or manures were applied. Exchangeable Mg content in post-harvest soil was decreased from its respective initial content after harvest of rice crop in all the approaches of fertilizer nutrient recommendations due to crop removal.

Table 5. Influence of difference approaches of fertilizer recommendations on secondary nutrients status of post harvest soil of aerobic rice

Treatments	S		Ca		Mg	
	(mg kg^{-1})		(cmol (p$^+$) kg^{-1})			
	Initial	After harvest	Initial	After harvest	Initial	After harvest
T_1	34.96	27.75	3.12	2.72	1.22	1.12
T_2	36.90	30.59	3.05	2.93	1.23	1.10
T_3	36.67	29.84	3.83	2.93	1.22	1.05
T_4	42.90	33.74	3.13	3.10	1.35	1.18
T_5	42.73	32.60	3.15	2.62	1.12	1.01
T_6	42.88	32.68	3.03	3.03	1.18	1.02
T_7	38.49	32.80	3.33	2.92	1.25	1.10
T_8	42.94	35.00	3.37	3.33	1.35	1.17
T_9	42.16	34.40	3.25	2.19	1.17	1.06
T_{10}	43.80	31.68	3.48	2.40	1.15	1.07
T_{11}	44.55	31.89	3.47	2.45	1.15	1.09
T_{12}	37.95	27.19	3.10	2.29	1.34	1.00
S.Em. ±		**2.10**		**0.22**		**0.12**
C.D. @ 5 %		**6.16**		**0.64**		**NS**

NS: Non significant

Table 6. Nitrogen balance in soil as influenced by different approaches of nutrient application

Treatment details	IAN	FN	TN	CU	EB	AB	G/L
	1	2	3(1+2)	4	5(3-4)	6	7(6-5)
T_1	260.59	143.94	404.53	161.94	242.59	261.33	18.74
T_2	207.10	154.80	361.90	176.73	185.17	264.69	79.53
T_3	261.67	127.56	389.23	151.50	237.73	267.09	29.36
T_4	205.62	138.95	344.57	159.71	184.86	280.37	95.51
T_5	260.21	113.72	373.93	150.90	223.03	265.07	42.04
T_6	202.89	125.37	328.26	162.21	166.06	266.20	100.14
T_7	262.08	98.55	360.63	143.73	216.90	266.93	50.04
T_8	201.60	110.84	312.44	146.17	166.26	277.39	111.12
T_9	272.53	100.00	372.53	126.61	245.92	268.61	22.69
T_{10}	266.56	125.00	391.56	110.37	281.19	268.95	-12.25
T_{11}	204.08	125.00	329.08	114.19	214.89	272.16	57.27
T_{12}	243.41	0.00	243.41	47.85	195.56	239.12	43.56

Legend: IAN = Initial available nitrogen (kg ha^{-1}) TN = Total nitrogen (kg ha^{-1}) FN = Fertilizer nitrogen (kg ha^{-1}) CU = Crop uptake (kg N ha^{-1}) EB = Expected balance (kg ha^{-1}) AB = Actual balance (kg ha^{-1}) G/L = Net gain/ net loss (kg ha^{-1})

3.11 Nitrogen Balance in Soil

The initial available nitrogen in soil ranged from 201.60 kg N ha^{-1} to 272.53 kg N ha^{-1} (Table 6) and higher dose of nitrogen was added (154.80 kg ha^{-1}) in STCR inorganic approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values (T_2). The maximum uptake of nitrogen (176.73 kg N ha^{-1}) by aerobic rice was recorded where fertilizer was applied as per STCR inorganic approach based on predicted soil test values for the targeted yield of 65 q ha^{-1} (T_2) followed by STCR target of 55 q ha^{-1} through inorganic approach based on predicted soil test values (162.21 kg N ha^{-1}) (T_6). Lower uptake of nitrogen (47.85 kg ha^{-1}) was recorded in absolute control (T_{12}) where no fertilizers or poultry manure was applied. The higher actual balance (280.37 kg N ha^{-1}) was recorded in STCR integrated approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values (T_4). However, overall net positive balance (111.12 kg N ha^{-1}) was higher in T_8 [STCR integrated (55 q ha^{-1}) - Predicted STV] followed by 100.14 kg ha^{-1} recorded in T_6 [STCR inorganics (55 q ha^{-1}) - Predicted STV]. The net negative balance of nitrogen (-12.25 kg ha^{-1}) was recorded in LMH approach where fertilizer nutrients were applied by considering actual soil test values. The higher actual balance of nitrogen in STCR integrated approaches was due to efficient use of applied nitrogen without wastage. These results were in accordance with the findings of Brar and Singh (1984) [17] who reported that the increase in available N in the post harvest soil might be due to the continuous mineralization of organic sources of N applied along with inorganic fertilizers.

3.12 Phosphorus Balance in Soil

The initial available phosphorus content in soil ranged from 56.96 kg ha^{-1} to 174.48 kg ha^{-1} (Table 7). The higher dose of phosphorus (73.54 kg ha^{-1}) was applied in STCR target of 65 q ha^{-1} through inorganic approach based on actual soil test values (T_1) where the soil available phosphorus was low (101.05 kg ha^{-1}) and the target was high (65 q ha^{-1}), whereas lower dose was applied in T_{10} and T_{11} (LMH approach through actual and predicted soil test values respectively). The maximum uptake of phosphorus (59.43 kg ha^{-1}) by aerobic rice was recorded where NPK fertilizers were applied as per STCR approach through inorganics based on predicted soil test values (T_2), whereas lower uptake was recorded in absolute control (17.48 kg ha^{-1}) where no fertilizers or poultry manure was applied. The higher actual balance (109.34 k g ha^{-1}) was recorded in T_2 [STCR inorganics (65 q ha^{-1}) - Predicted STV]. Interestingly, all the treatments of various approaches of fertilizer recommendations except absolute control and STCR target of 55 q ha^{-1} through integrated approach based on actual soil test values recorded net negative balance of phosphorus may due to fixation of applied phosphorus. This could be due to conversion of plant available form of phosphorus to plant unavailable form (Al-P, Fe-P and Ca-P). Tomar (2000) [18] reported that nearly 60 to 70 per cent of the applied phosphorus has been found to remain fixed in the form of Al-P, Fe-P and Ca-P after harvest of rice crop, which corroborated with the results of the present study.

3.13 Potassium Balance in Soil

The initial available potassium content in soil ranged from 168.13 kg ha^{-1} to 456.03 kg ha^{-1} (Table 8). The higher dose of applied potassium (50 kg ha^{-1}) was noticed in LMH approach based on both actual and predicted soil test values, whereas lower dose was applied (2.12 kg ha^{-1}) in T_4 (STCR integrated (65 q ha^{-1}) - Predicted STV) where the initial available potassium was very high (456.03 kg ha^{-1}). The maximum uptake of potassium (175.70 kg ha^{-1}) was recorded in STCR target of 65 q ha^{-1} through integrated approach using predicted soil test values (T_2), whereas, lower uptake of K_2O was recorded in absolute control (43.63 kg ha^{-1}) where no fertilizers or poultry manure was applied. The higher actual balance (297.52 kg ha^{-1}) was recorded in STCR integrated approach for the targeted yield of 65 q ha^{-1} through predicted soil test values (T_4). Interestingly, all the treatments of various approaches of fertilizer recommendations recorded net positive balance of potassium. The higher actual balance of potassium in these treatments might be due to incorporation of poultry manure or any organic

Table 7. Phosphorus balance in soil as influenced by different approaches of nutrient application

Treatments	IAP	FP	TP	CU	EB	AB	G/L
	1	2	3(1+2)	4	5(3-4)	6	7(6-5)
T_1	101.05	73.54	174.59	55.81	118.78	100.81	-17.97
T_2	174.48	68.13	242.61	59.43	183.18	109.34	-73.84
T_3	106.92	61.25	168.17	53.85	114.33	99.18	-15.15
T_4	167.74	57.08	224.82	55.96	168.86	104.30	-64.55
T_5	99.88	61.16	161.04	53.99	107.05	103.24	-3.81
T_6	149.36	56.85	206.21	55.98	150.22	105.43	-44.79
T_7	93.65	50.85	144.50	50.32	94.18	101.47	7.29
T_8	145.27	47.26	192.53	51.46	141.07	103.32	-37.75
T_9	115.60	50.00	165.60	42.43	123.17	102.21	-20.96
T_{10}	98.55	37.50	136.05	38.67	97.38	88.61	-8.77
T_{11}	165.92	37.50	203.42	40.67	162.75	93.74	-69.01
T_{12}	56.96	0.00	56.96	17.48	39.48	57.51	18.03

Legend: IAP = Initial available phosphorus (kg ha^{-1}), TP = Total phosphorus (kg ha^{-1}) FP = Fertilizer phosphorus (kg P_2O_5 ha^{-1}) CU = Crop uptake (kg P_2O_5 ha^{-1}), EB = Expected balance (kg ha^{-1}) AB = Actual balance (kg ha^{-1}) G/L = Net gain/ net loss (kg ha^{-1})

Table 8. Potassium balance in soil as influenced by different approaches of nutrient application

Treatments	IAK	FK	TK	CU	EB	AB	G/L
	1	2	3(1+2)	4	5(3-4)	6	7(6-5)
T_1	271.64	36.82	308.46	173.12	135.34	217.36	82.02
T_2	298.07	30.84	328.91	175.70	153.21	229.08	75.87
T_3	305.92	28.96	334.88	165.66	169.22	291.20	121.98
T_4	456.03	2.12	458.15	170.85	287.30	297.52	10.22
T_5	221.67	33.01	254.68	150.08	104.60	216.60	112.00
T_6	276.69	20.56	297.25	153.03	144.22	222.40	78.18
T_7	245.75	26.62	272.37	141.91	130.45	221.88	91.43
T_8	340.47	6.62	347.09	141.18	205.91	249.44	43.53
T_9	286.76	50.00	336.76	144.71	192.05	274.30	82.25
T_{10}	285.69	50.00	335.69	120.77	214.93	283.72	68.79
T_{11}	322.27	45.83	368.10	130.63	237.47	289.04	51.57
T_{12}	168.13	0.00	168.13	43.63	124.50	166.20	41.70

Legend: IAK = Initial available potassium (kg ha^{-1}), TK = Total potassium (kg ha^{-1}) FK = Fertilizer potassium (kg K_2O ha^{-1}) CU = Crop uptake (kg K_2O ha^{-1}), EB = Expected balance (kg ha^{-1}) AB = Actual balance (kg ha^{-1}) G/L = Net gain/ net loss (kg ha^{-1})

sources along with fertilizer nitrogen (synergistic effect of N on K) which increased the cumulative non exchangeable K release and maintained greater amount of potassium in solution and on exchange sites, by re-establishing the equilibrium among the different fractions of potassium [19], thereby enhanced the available K_2O in the soil.

4. CONCLUSION

Among various approaches of fertilizer recommendations, higher post- harvest soil available nutrient status was registered in STCR integrated approach based on predicted soil test values which indicates the maintenance of soil fertility status. No significant difference was observed between the actual and predicted soil test value based fertilizer recommendation with respect to soil available nutrients which indicates that predicted soil test values could be used with confidence to prescribe the fertilizer dose in a cropping sequence.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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