Yield and budgeting of nutrients in rice-cowpea cropping system after harvest in alfisols of Karnataka

ABSTRACT

A field experiment was undertaken at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India to study the primary nutrients budgeting in rice-cowpea cropping system in an alfisols.Hybrid rice was tested under aerobic condition during *Kharif* 2015-16 and 2016-17 with 16 treatments replicated thrice in randomized block design. Treatments includes Control, 100% RDF through conventional fertilizers (CF) as per package of practice (PoP), application of RDF with CF through fertigation at 4 and 8 days interval and with different doses (30, 50 & 100%) of fertilisers through recommended dose of fertilizers (RDF) and soil test crop response (STCR) approaches using water soluble fertilizers (WSF) through fertigation at 4 and 8 days interval (DI)and their residual effect was studied during summer 2016-17 and 2017-18 with cowpea as a test crop. Significantly higher grain (62.98q ha^{-1}) and straw (85.26 q ha^{-1}) yield of rice was recorded in treatment,which received 100% STCR dose through WSF at 8 DI.The treatment with 100% STCR dose through WSFat 8 DI has recorded significantly higher total uptake ofN,P and K by rice (220.68, 44.97 and 137.41 kg N, P and K ha^{-1}, respectively).Significantly higher seed yield (12.94 q ha^{-1}) and haulm yield (26.17 q ha^{-1}) of cowpea was recorded in fertigation with 100% RDF through WSFat 8 DI. Significantly higher total uptake of N, P and Kby cowpea (68.94, 14.67 and 61.39 kg N, P and K ha^{-1}, respectively) was recorded in 100% RDF through WSF at 4 DI.The maximum net positive balance (148.42 kg N ha^{-1}) was noticed in 100% RDF applied through WSF at 8 DI and minimum net positive balance 53.86 kg N ha^{-1} was recorded in 100% RDF-CF.During 2016-17, after the completion of second year residual crop cowpea, the maximum net positive balance (148.42 kg N ha^{-1}) was noticed in 100% RDF applied through WSF at 8 DI and minimum net positive balance 53.86 kg N ha^{-1} was recorded in 100% RDF-CF. The maximum net positive balance (38.27 kg ha^{-1}) was recorded in 100% STCR dose -WSF 8 DI and minimum net negative balance (15.70 kg P_2O_5 ha^{-1}) was recorded in 100% RDF-CF.The maximum net positive balance of potassium (98.27 kg K_2O ha^{-1}) was recorded in 100% RDF-WSF 4DIand minimum net positive balance (24.61 kg K_2O ha^{-1}) was recorded in 100% RDF-CF 8 DItreatment.

Key words: Fertigation, STCR, RDF, WSF, CF, Cowpea, soil properties

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INTRODUCTION

Nutrients, such as nitrogen, phosphorus and potassium, provide vital support for human life, but overloading of these nutrients to the earth system leads to environmental concerns, such as soil, water and air pollution on local scales. With an urgent need to feed the world's growing population and the growing concern over nutrient pollution and climate change, sustainable nutrient management has become a major challenge for this century(Umilsinghe*et al.*2023). The intensive use of nutrients in agricultural production, along with their use in other human activities, has largely distorted the nutrient cycles in the Earth system, especially for the macronutrients, nitrogen (N), and phosphorus (P). Consequently, it is imperative to improve nutrient management in order to feed the population with nutritious food while minimizing unintended and undesirable environmental impacts. However, improving nutrient use requires the ability to measure and monitor the fates of nutrients that are cycling within and escaping from ecosystems, but nutrient budgets have been difficult to quantify. The nutrient budget of a *Soil-Plant* system, also called soil surface budget or nutrient balance, considers the soil and the plants growing in it as an integrated system and accounts for the inputs and outputs of the integrated system. To address this challenge, the growing body of research on nutrient budgets, namely the nutrient inputs and outputs of a given system, has provided great opportunities for improving scientific knowledge of the complex nutrient cycles in the coupled human and natural systems. The objective of this paper is to know the gain or loss of primary nutrients in the soil after rice-cowpea cropping system in an alfisols.

MATERIAL AND METHODS

The experiment was conducted with sixteen treatments replicated thrice times during *Kharif* 2015 and 2016 with hybrid rice (KRH-4) as the test crop and their residual effect on cowpea crop (KM-5) which was grown during summer seasons of 2016 and 2017 at ZARS, GKVK, Bangalore. Two years pooled data of aerobic rice crop was collected and analyzed in RCBD design. Treatments comprised of T_1:Control (without NPK fertilizers), T_2:100% RDF-Conventional fertilizers through soil application as per PoP, T_3:100% RDF-Conventional fertilizers through fertigation at 4 days interval (DI), T_4:100% RDF-Conventional fertilizers through fertigation at 8 DI, T_5:100% RDF-Water soluble fertilizers through fertigation at 4 days interval, T_6:50% RDF-Water soluble fertilizers through fertigation at 4 DI, T_7:30% RDF-Water soluble fertilizers through fertigation at 4 DI, T_8:100% RDF-Water soluble fertilizers through fertigation at 8 DI, T_9:50% RDF-Water soluble fertilizers through fertigation at 8 DI, T_{10}:30% RDF-Water soluble fertilizers through fertigation at 8 DI, T_{11}:100% STCR-Water soluble fertilizers through fertigation at 4 days interval, T_{12}:50% STCR-

Water soluble fertilizers through fertigation at 4 DI, T_{13}:30% STCR-Water soluble fertilizers through fertigation at 4 DI, T_{14}:100% STCR-Water soluble fertilizers through fertigation at 8 DI, T_{15}:50% STCR-Water soluble fertilizers through fertigation at 8 DI and T_{16}:30% STCR-Water soluble fertilizers through fertigation at 8 DI.

For hybrid rice, as per the package of practice the recommended dose of farm yard manure @ 10 t ha^{-1} was incorporated into the soil 20 days before sowing, $ZnSO_4$ @ 20 kg ha^{-1} and N, P_2O_5, K_2O @ 125:62.5:62.5 kg ha^{-1}, respectively were applied as per the treatments expect for the absolute control treatment. For treatment T_2, where N was applied in three split doses *viz.*, 50% as basal, the remaining 50% nitrogen was top dressed in two equal splits during active tillering and before panicle initiation stage, 100% P nutrient was applied at the time of sowing and K was applied in two equal splits as basal and at active tillering stage through conventional fertilizers *viz.*, urea, single super phosphate and muriate of potash, respectively. Basal dose of fertilizers wereapplied at the time of sowing @ 30%, 50% and 30% (N, P_2O_5 andK_2O, respectively)from T_3 to T_{16} treatments. For T_3 and T_4 treatments, in which the remaining 70%, 50% and 70% of N, P_2O_5 andK_2O, respectively were supplied through conventional fertilizers at 4 (15 times) and 8 (8 times) days interval of fertigation. Further, for the water soluble fertilizers treatments (*viz.*,T_5,T_6,T_7,T_{11},T_{12} & T_{13} and T_8,T_9,T_{10},T_{14},T_{15}& T_{16})theremaining 70%, 50% and 70% of N, P_2O_5 and K_2O, respectively were done through different grades of water soluble fertilizers *viz.*, 19:19:19 (19 all), Mono Potassium Phosphate (MPP), Mono ammonium phosphate (MAP), Sulphate of Potash (SOP) and Calcium nitrate (CN) at 4 (15 times) and 8 (8 times) days interval of fertigation.The fertigation was done through venturysystem starting from 20 days after sowing and continued up to 80 days after sowing or panicle initiation stage to each plot as per the treatments. Irrigation schedule was common for all the treatments. In both the years, after the harvest of the aerobic rice, land preparation was carried out, in summer season and cowpea was taken as a suceedingcrop to check the residual effect of fertigation of water soluble fertilizers.

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The initial soil samples were collected from each plot separately before conducting the experiment and soil samples were air dried, powdered, sieved and stored in plastic cover. And analysis was carried out for different physical and chemical properties as per standard procedures. Similarly, after the harvest of the aerobic rice, the soil samples were collected in each plot from both the years and analysis was done as per the standard procedures. The experimental field soil is sandy clay loam in texture and neutral in soil reaction (6.72). The initial fertility status of soil showed low OC (0.48%) content. And the soil was low in available N content, medium in available P_2O_5 and K_2O (212.59, 21.98 and 210.43 kg ha^{-1}, respectively) and sufficient amount of exch. Ca and Mg (3.96 and

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2.63 [cmol (p^+) kg^{-1}], respectively) and available S (17.60 ppm) content in present in soil. DTPA extractable micronutrients *viz.*, (Fe-18.28, Zn-1.65, Mn-23.91and Cu-0.61 ppm) content in the soil was above critical levels.

The quantity of fertilizers for STCR treatments (T_{11} to T_{16}) required for a yield of 80 q ha^{-1} were calculated (Table 1) by using STCR targeted yield equation developed at ZARS, V.C. Farm, Mandya(Prakash *et al*. 2007) and it as follows,

$FN = 5.166\ T - 0.799\ SN \times KMnO_4.N - 9.67 \times OM$

$FP_2O_5 = 1.636\ T - 0.256\ SP_2O_5 \times Olsen.P_2O_5 - 0.77 \times OM$

$FK_2O = 2.31T - 0.493\ SK_2O \times Amm.Ace.K_2O - 1.14 \times OM$

Where,

T =Targeted yield (q ha^{-1}) *i.e*. 80 q ha^{-1}

FN =Fertilizer nitrogen (kg ha^{-1})

FP_2O_5 =Fertilizer phosphorus (kg ha^{-1})

FK_2O =Fertilizer potassium (kg ha^{-1})

OM=Organic manure (FYM) (kg ha^{-1})

SN, SP_2O_5 and SK_2O are initial available N, P_2O_5 and K_2O kg ha^{-1}, respectively.

Table 1: Quantity of NPK nutrients applied for different treatments through different approaches during 2015-16 and 2016-17

Treatments	Quantity of NPK nutrients applied (kg ha^{-1})					
	2015-16			2016-17		
	N	P	K	N	P	K
T_1-Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2-100% RDF-CF	125.00	62.50	62.50	125.00	62.50	62.50
T_3-100% RDF-CF 4 DI	125.00	62.50	62.50	125.00	62.50	62.50
T_4-100% RDF-CF 8 DI	125.00	62.50	62.50	125.00	62.50	62.50
T_5-100% RDF-WSF 4DI	125.00	62.50	62.50	125.00	62.50	62.50
T_6-50% RDF-WSF 4DI	62.50	31.25	31.25	62.50	31.25	31.25
T_7-30% RDF-WSF 4 DI	37.50	18.75	18.75	37.50	18.75	18.75
T_8-100% RDF-WSF 8 DI	125.00	62.50	62.50	125.00	62.50	62.50
T_9-50% RDF-WSF 8 DI	62.50	31.25	31.25	62.50	31.25	31.25
T_{10}-30% RDF-WSF 8 DI	37.50	18.75	18.75	37.50	18.75	18.75
T_{11}-100% STCR dose -WSF 4 DI	154.61	118.50	68.43	196.66	92.80	107.65
T_{12}-50% STCR dose -WSF 4 DI	76.74	58.60	38.21	106.15	52.54	58.36
T_{13}-30% STCR dose -WSF 4 DI	45.87	35.21	21.74	65.87	33.01	35.69
T_{14}-100% STCR dose -WSF 8 DI	148.08	116.71	71.71	200.73	93.99	110.45

T_{15}-50% STCR dose -WSF 8 DI	74.98	59.02	35.62	108.10	53.48	57.52
T_{16}-30% STCR dose -WSF 8 DI	44.23	34.84	20.35	66.72	33.00	35.82

RESULTS AND DISCUSSION

Grain and straw yield of aerobic rice

Significantly higher grain (62.98 q ha^{-1}) and straw (85.26 q ha^{-1}) yield of rice were recorded in treatmentwhich received fertigation with 100% STCR dose through water soluble fertilizers at 8 DI (Fig 1).Thismay be ascribed to its complete solubility of WSFand enhanced availability of nutrients near effective root zone resulted in more uptake of nutrients which would have helped in higher yield in STCR targeted yield approach. Similar findings were stated by Raina *et al*. (2011); Hebbar *et al*. (2004) and Anusha (2015); Anitta (2013), Tadesse *et al*. (2013) and Pradeep Kumar, Parmanand (2018) and (Umilsingh*et al*.2024).

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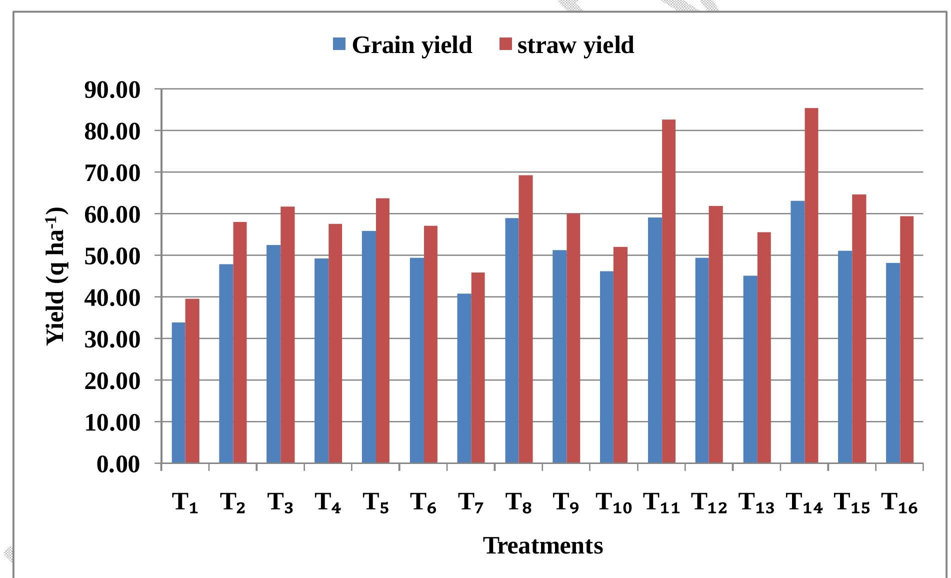

Fig 1:Effect of different approaches, forms, doses and intervals of fertilizer application ongrain and straw yield of aerobic rice under aerobic rice -cowpea cropping sequence

Total uptake of major nutrients by aerobic rice

The treatment with 100% STCR dose through water soluble fertilizers at 8 DI has recorded significantly higher total uptake N,P and K by rice (220.68, 44.97 and 137.41 kg N,P and K ha^{-1}, respectively) and data presented in Table 2.This may be due to frequent supply of easily soluble form of NPK nutrients have been uniformly distributed better throughout the root zone of rice along with irrigation water in fertigation treatments resulted in availability of more nutrients in soil for plant uptake in drip fertigation with WSF through STCR approach than soil application of conventional fertilizers. Similar results were observed by Hebbar *et al*. (2004) in tomato crop andRaina *et al.* (2011) in apricot.

Table 2: Effect of different approaches, forms, doses and intervals of fertilizer application on total uptake of N,P and K by rice under aerobic rice-cowpea cropping sequence

Treatments	Total NPK uptake (kg ha^{-1})		
	N	**P**	**K**
T_1-Control	102.99	18.53	54.58
T_2-100% RDF-CF	140.45	27.14	89.30
T_3-100% RDF-CF 4 DI	162.62	29.75	98.22
T_4-100% RDF-CF 8 DI	157.09	27.31	90.30
T_5-100% RDF-WSF 4 DI	194.06	41.18	127.50
T_6-50% RDF-WSF 4 DI	144.61	31.17	77.45
T_7-30% RDF-WSF 4 DI	118.13	26.14	59.53
T_8-100% RDF-WSF 8 DI	201.24	42.15	126.67
T_9-50% RDF-WSF 8 DI	148.86	31.03	80.33
T_{10}-30% RDF-WSF 8 DI	131.38	28.46	60.85
T_{11}-100% STCR dose -WSF 4 DI	205.45	43.15	131.50
T_{12}-50% STCR dose -WSF 4 DI	143.77	31.80	81.44
T_{13}-30% STCR dose -WSF 4 DI	128.68	27.47	61.66
T_{14}-100% STCR dose -WSF 8 DI	220.68	44.97	137.41
T_{15}-50% STCR dose -WSF 8 DI	154.89	32.80	80.23
T_{16}-30% STCR dose -WSF 8 DI	139.52	29.84	65.32
SEm ±	**007.42**	**01.56**	**02.24**
CD at 5%	**020.98**	**04.40**	**06.35**

Seed yieldand haulm yield of cowpea

The fertigation with 100% RDF through water soluble fertilizers at 8 DI treatment was recorded (Fig 2) significantly higher seed and haulm yield (12.94 and 26.17 q ha^{-1}, respectively).This might be due to application of higher dose (100%) of NPK fertilizer through RDF or STCR approach to preceding aerobic rice crop attributed for higher residual NPK nutrients in soil before sowing of cowpea might have resulted in better root nodulation and nitrogen fixation and also utilization of inexhaustible atmospheric nitrogen through biological nitrogen fixation which might have helped in maintaining soil fertility. Higher level of biomass accumulation and efficient translocation and assimilation of photosynthates to thereproductive parts due to supply of adequate nutrients might be responsible for production of elevated level of yield structure. The results of present study are in conformation with those reported by Gawain and Pawar (2005).

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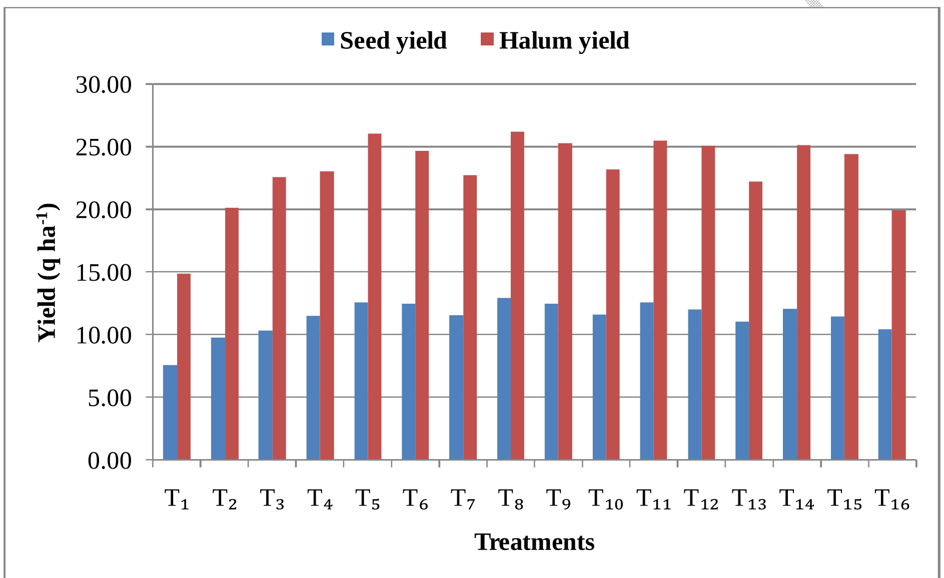

Fig 2: Effect of fertigation of water soluble fertilizers on seed and haulm yield of cowpeaunder rice-cowpea cropping sequence

Total uptake of major nutrients by cowpea

Significantly higher total uptake ofN, P and Kby cowpea (68.94,14.67 and 61.39 kg N,P and K ha^{-1}, respectively) were recorded in 100% RDF through water soluble fertilizers at 4 DI(Table 3).The higher uptake of N, P and K by cowpea crop might be due to higher biomass production coupled with higher availability of residual nitrogen, phosphorus and potassium in the soil after harvest of rice crop. The better performance of growth and yield of cowpea further traced back to the improvement in nutrient uptake. Similar findings were also observed by Dinesh (2014) who reported that the application of organic manure about one third of total N, half of total P is available to first crop and rest of N and P are available to the succeeding crop as residual effect.

Table 3: Residual effect of different approaches, forms, doses and intervals of fertilizer application on total uptake of N, P and K by cowpea under aerobic rice-cowpea cropping sequence

Treatments	Total NPKuptake ($kg\ ha^{-1}$)		
	N	**P**	**K**
T_1-Control	34.73	7.94	32.55
T_2-100% RDF-CF	49.25	11.40	44.36
T_3-100% RDF-CF 4 DI	51.89	12.79	49.62
T_4-100% RDF-CF 8 DI	53.88	12.41	51.61
T_5-100% RDF-WSF 4 DI	68.94	14.67	61.39
T_6-50% RDF-WSF 4 DI	61.62	13.28	55.51
T_7-30% RDF-WSF 4 DI	53.26	12.00	50.79
T_8-100% RDF-WSF 8 DI	67.07	14.65	60.03
T_9-50% RDF-WSF 8 DI	61.96	12.64	54.81
T_{10}-30% RDF-WSF 8 DI	55.31	11.54	49.42
T_{11}-100% STCR dose -WSF 4 DI	65.86	14.09	56.31
T_{12}-50% STCR dose -WSF 4 DI	57.78	12.56	53.49
T_{13}-30% STCR dose -WSF 4 DI	51.40	11.49	49.26
T_{14}-100% STCR dose -WSF 8 DI	61.76	13.67	55.91
T_{15}-50% STCR dose -WSF 8 DI	54.51	12.24	51.90
T_{16}-30% STCR dose -WSF 8 DI	46.76	10.48	44.18
SEm ±	**2.42**	**0.43**	**2.73**
CD at 5%	**6.83**	**1.23**	**7.70**

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizers, CF: Conventional fertilizers, DI: Days interval, NS: Non significant

Balance sheet of available NPK in soil as influenced by different approaches, forms, doses andintervals of fertilizer application under rice-cowpea cropping system (2015-16 and 2016-17)

The initial nutrient status (NPK) of soil before sowing of aerobic rice was analysed and recorded. The nutrients were added through chemical fertilizers accounts to total nutrient in soil. The removal of nutrients by the rice and cowpea crops was quantified after the harvest of both the crops. The expected balance, actual balance and net gain/loss of nutrients were calculated during both the seasons separately.

N balance sheet

During 2015-16, among 16 treatments the initial available N in soil varied from 201.60 to 225.87 kg N ha^{-1} and data is presented in Table 4. Maximum uptake of nitrogen by aerobic rice and cowpea together (289.23 kg N ha^{-1}) from the soil was recorded in treatment receiving 100% NPK applied through STCR with WSF at 8 DI.The lower uptake (141.28 kg N ha^{-1}) was noticed in control treatment, where no fertilizers and FYM were applied.However, actual balance was higher (150.08 kg N ha^{-1}) in 100% STCR dose -WSF 4 DIand lower value was noticed in control (106.12 kg N ha^{-1}). The maximum net positive balance (88.42 kg N ha^{-1}) was recorded in 100% RDF-WSF 4 DI, but net negative balance (-12.52 kg N ha^{-1}) was recorded in 100% RDF-CF, where 100% RDF was applied through conventional fertilizer as per PoP.

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In 2016-17, the initial available N content in soil varied from 106.12 to 150.08 kg N ha^{-1} between the 16 treatments in the present investigation (Table 5). The higher uptake of nitrogen by aerobic rice and cowpea (275.65 kg N ha^{-1}) from the soil was recorded in treatment receiving 100% NPK applied through STCR approach with WSF at 8 DI.The lowest uptake (134.16 kg N ha^{-1}) was noticed in control treatment, where no fertilizers and FYM were applied. However, actual balance of N was higher (142.67 kg N ha^{-1}) in 100% STCR dose -WSF 4 DIand lower value (77.67 kg N ha^{-1}) was noticed in control.The maximum net positive balance (148.42 kg N ha^{-1}) was noticed in 100% RDF applied through WSF at 8 DI and minimum net positive balance 53.86 kg N ha^{-1} was recorded in 100% RDF-CF.

P balance sheet

The initial available P_2O_5 content in soil varied from 17.56 to 27.52 kg P_2O_5 ha^{-1} during 2015-16 and furnished in Table 6. The highest uptake of phosphorus by aerobic rice and cowpea together (60.23 kg P_2O_5 ha^{-1}) from the soil was recorded in treatment receiving 100% NPK applied through STCR with WSF at 8 DI.The lowest uptake (26.70 kg P_2O_5 ha^{-1}) was noticed in control treatment, where no fertilizers and FYM were applied. However, actual phosphorus balance was higher (118.67 kg P_2O_5 ha^{-1}) in 100% STCR dose -WSF 4 DI and lower value was noticed in control (19.67 kg P_2O_5 ha^{-1}). The maximum net positive balance (39.84 kg P_2O_5 ha^{-1}) was higher in 100% STCR dose -WSF 4 DIand minimum net positive balance (15.92 kg P_2O_5 ha^{-1}) was recorded in 100% RDF-CF.

In 2016-17, among the different treatments, the initial available P_2O_5 in soil varied from 19.67 to 118.67 kg P_2O_5 ha^{-1} (Table 7). Maximum uptake of phosphorus by aerobic rice and cowpea together (57.61 kg P_2O_5 ha^{-1}) from the soil was recorded in treatment receiving 100% NPK applied through RDF with WSF at 8 DI. The lowest uptake (26.24 kg P_2O_5 ha^{-1}) was noticed in control treatment where no fertilizers and FYM were applied. However, actual balance was higher (130.75 kg P_2O_5 ha^{-1}) in 100% STCR dose -WSF 4 DI and lower value (13.67 kg P_2O_5 ha^{-1}) was noticed in control and maximum net positive balance (38.27 kg ha^{-1}) was recorded in 100% STCR dose -WSF 8 DI and minimum net negative balance (15.70 kg P_2O_5 ha^{-1}) was recorded in 100% RDF-CF**.**

K balance sheet

During 2015-16, the initial available K_2O in soil varied from 193.33 to 234.13 kg K_2O ha^{-1} (Table 8). Higher uptake of potassium by aerobic rice and cowpea together (193.20 kg K_2O ha^{-1}) from the soil was recorded in 100% NPK applied through STCR with WSF at 8 DI. The lowest uptake (89.43 kg K_2O ha^{-1}) was noticed in control treatment, where no fertilizers and FYM were applied. However, actual balance was higher (133.10 kg K_2O ha^{-1}) in 100% STCR dose -WSF 4 DI and lower value was noticed in control (97.85 kg K_2O ha^{-1}). The net positive balance (43.06 kg K_2O ha^{-1}) was higher in 100% STCR dose -WSF 8 DIand maximum net negative balance (25.12 kg K_2O ha^{-1}) was recorded in controltreatment.

Among the 16 different treatments, the initial available K_2O in soil varied from 97.85 to 133.10 kg K_2O ha^{-1} during 2016-17 and data is presented in Table 9. Maximum uptake of potassium by aerobic rice and cowpea together (193.45 kg K_2O ha^{-1}) from the soil was recorded in 100% NPK applied through STCR with WSF at 8 DI. The lowest uptake (84.85 kg K_2O ha^{-1}) was noticed in control treatment where no fertilizers and FYM were applied. However, actual balance of K was higher (127.24 kg K_2O ha^{-1}) in 100% STCR dose -WSF 4 DIand lower value (63.00 kg K_2O ha^{-1}) was noticed in control and maximum net positive balance of potassium (98.27 kg K_2O ha^{-1}) was recorded in 100% RDF-WSF 4 DIand minimum net positive balance (24.61 kg K_2O ha^{-1}) was recorded in 100% RDF-CF 8 DItreatment.

Balanced nutrient management in cropping systems which can maintain the good soil health, thereby minimizing environmental pollution, is a cost-effective and environmentally friendly approach to target agricultural sustainability. Tanmoy *et al*. (2021) concluded the application of ample doses of recommended nutrients is essential to maintain a positive nutrient balance. The rice-legume systems, which has the opportunity to replenish a portion of the nutrients (more specifically N) through biological N fixation and nutrient recycling. The control treatment (no fertilizer application) yielded less with the least nutrient uptake and omission of any nutrient, as well as a control treatment, resulted in a negative nutrient balance, which is synonymous with depletion of soil fertility. Senthivelu*et al*. (2007) reported that significantly higher amount of nutrient uptake, post harvest nutrient availability and positive balance of NPK was observed in FYM @12.5 t ha^{-1} and

100% inorganicrecommended NPK(112.5:37.5:37.5 kg ha^{-1}) alone and net negative nutrient balance was observed in the control treatment.Ajeet *et al.* (2017) concluded that combined application of fertilizer and irrigation levels in cauliflower could be a sustainable practice to enhance nutrients balance in the soil and improved soil fertility. Nutrient supply through drip fertigation enabled greater uptake of NPK by reducing the nutrient loss in the soil and enhances the nutrient availability throughout the cropping period hence sustaining the nutrient status of the soil. Bhavya *et al*. (2019) concluded that STCR approach of fertilizer application specially with IPNS approach is more suitable not only for getting higher yield but also helps in efficient and balanced use of fertilizer nutrients to get a higher positive balance of applied major nutrients in the soil. In the present study, FYM was applied to all the plots and hence all the treatments recorded positive balance except control. Similar results were mentioned by Muneshwar Singh *et al*. (2002).

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Table 4: Nitrogen balance in soil as influenced by different approaches, forms, doses and intervals of fertilizer application on rice under aerobic rice-cowpea cropping system (2015-16)

Treatments	Initial Available N (kg ha^{-1})	Addition of N through fertilizer (kg ha^{-1})	Total N (kg ha^{-1})	Crop uptake of N (kg ha^{-1})	Expected balance N (kg ha^{-1})	Actual available N (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	202.25	0.00	202.25	141.28	60.97	106.12	45.15
T_2-100% RDF-CF	206.73	125.00	331.73	186.88	146.00	132.33	-12.52
T_3-100% RDF-CF 4 DI	210.91	125.00	335.91	218.70	117.21	140.33	23.12
T_4-100% RDF-CF 8 DI	207.44	125.00	332.44	211.75	120.69	139.33	18.65
T_5-100% RDF-WSF 4 DI	201.60	125.00	326.60	269.35	57.25	145.67	88.42
T_6-50% RDF-WSF 4 DI	203.00	62.50	265.50	214.93	50.57	123.39	72.83
T_7-30% RDF-WSF 4 DI	225.87	37.50	263.37	175.32	88.05	126.52	38.47
T_8-100% RDF-WSF 8 DI	205.80	125.00	330.80	273.21	57.59	130.33	72.74
T_9-50% RDF-WSF 8 DI	208.13	62.50	270.63	223.08	47.55	113.40	65.85
T_{10}-30% RDF-WSF 8 DI	214.03	37.50	251.53	192.24	59.29	111.26	51.98
T_{11}-100% STCR dose -WSF 4 DI	202.72	154.61	357.33	276.00	81.33	150.08	68.76
T_{12}-50% STCR dose -WSF 4 DI	204.12	76.74	280.86	206.30	74.57	130.52	55.95
T_{13}-30% STCR dose -WSF 4 DI	204.84	45.87	250.71	184.28	66.43	121.40	54.97
T_{14}-100% STCR dose -WSF 8 DI	210.89	148.08	358.97	289.23	69.74	145.00	75.26
T_{15}-50% STCR dose -WSF 8 DI	208.53	74.98	283.51	213.99	69.52	125.64	56.12
T_{16}-30% STCR dose -WSF 8 DI	211.68	44.23	255.91	191.21	64.70	117.86	53.16

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Table 5: Nitrogen balance in soil as influenced by different approaches, forms, doses and intervals of fertilizer application on rice under aerobic rice-cowpea cropping system (2016-17)

Treatments	Initial available N (kg ha^{-1})	Addition of N through fertilizer (kg ha^{-1})	Total N (kg ha^{-1})	Crop uptake of N (kg ha^{-1})	Expected balance N (kg ha^{-1})	Actual available N (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	106.12	0.00	106.12	134.16	-28.04	77.67	105.70
T_2-100% RDF-CF	132.33	125.00	257.33	192.52	64.81	118.67	53.86
T_3-100% RDF-CF 4 DI	140.33	125.00	265.33	210.32	55.02	128.00	72.98
T_4-100% RDF-CF 8 DI	139.33	125.00	264.33	210.19	54.14	121.13	66.98
T_5-100% RDF-WSF 4 DI	145.67	125.00	270.67	256.65	14.02	128.33	114.31
T_6-50% RDF-WSF 4 DI	123.39	62.50	185.89	197.53	-11.63	102.00	113.63
T_7-30% RDF-WSF 4 DI	126.52	37.50	164.02	167.45	-3.42	105.80	109.22
T_8-100% RDF-WSF 8 DI	130.33	125.00	255.33	263.42	-8.09	140.33	148.42
T_9-50% RDF-WSF 8 DI	113.40	62.50	175.90	198.54	-22.65	105.00	127.65
T_{10}-30% RDF-WSF 8 DI	111.26	37.50	148.76	181.13	-32.37	97.85	130.22
T_{11}-100% STCR dose -WSF 4 DI	150.08	196.66	346.75	266.62	80.13	142.67	62.54
T_{12}-50% STCR dose -WSF 4 DI	130.52	106.15	236.67	196.80	39.87	130.06	90.20
T_{13}-30% STCR dose -WSF 4 DI	121.40	65.87	187.28	175.87	11.41	109.33	97.93
T_{14}-100% STCR dose -WSF 8 DI	145.00	200.73	345.73	275.65	70.08	138.48	68.40
T_{15}-50% STCR dose -WSF 8 DI	125.64	108.10	233.74	204.82	28.92	120.91	91.99
T_{16}-30% STCR dose -WSF 8 DI	117.86	66.72	184.58	181.35	3.23	101.60	98.37

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Table 6: Phosphorous balance in soil as influenced by different approaches, forms, doses and intervals offertilizer application on rice under aerobic rice- cowpea cropping system (2015-16)

Treatments	Initial available P_2O_5 (kg ha^{-1})	Addition of P_2O_5 through fertilizer (kg ha^{-1})	Total P_2O_5 (kg ha^{-1})	Crop uptake of P_2O_5 (kg ha^{-1})	Expected balance P_2O_5 (kg ha^{-1})	Actual available P_2O_5 (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	25.81	0.00	25.81	26.70	-0.89	19.67	20.56
T_2-100% RDF-CF	20.43	62.50	82.93	39.52	43.41	59.33	15.92
T_3-100% RDF-CF 4 DI	17.56	62.50	80.06	42.58	37.48	74.43	36.95
T_4-100% RDF-CF 8 DI	21.51	62.50	84.01	39.10	44.91	63.15	18.24
T_5-100% RDF-WSF 4 DI	20.79	62.50	83.29	55.16	28.13	64.42	36.29
T_6-50% RDF-WSF 4 DI	21.15	31.25	52.40	45.85	6.55	42.65	36.10
T_7-30% RDF-WSF 4 DI	22.23	18.75	40.98	38.04	2.94	36.91	33.97
T_8-100% RDF-WSF 8 DI	20.79	62.50	83.29	55.98	27.31	63.39	36.09
T_9-50% RDF-WSF 8 DI	20.79	31.25	52.04	45.18	6.86	40.93	34.07
T_{10}-30% RDF-WSF 8 DI	23.30	18.75	42.05	40.20	1.85	33.52	31.67
T_{11}-100% STCR dose -WSF 4 DI	18.28	118.50	136.78	57.96	78.82	118.67	39.84
T_{12}-50% STCR dose -WSF 4 DI	23.38	58.60	81.97	45.33	36.64	70.69	34.05
T_{13}-30% STCR dose -WSF 4 DI	22.77	35.21	57.97	39.81	18.16	51.38	33.22
T_{14}-100% STCR dose -WSF 8 DI	25.26	116.71	141.98	60.23	81.74	114.04	32.29
T_{15}-50% STCR dose -WSF 8 DI	20.07	59.02	79.09	45.41	33.68	63.37	29.69
T_{16}-30% STCR dose -WSF 8 DI	27.52	34.84	62.36	40.56	21.80	51.52	29.72

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Table7: Phosphorous balance in soil as influenced by different approaches, forms, doses and intervals of fertilizer application on rice under aerobic rice-cowpea cropping system (2016-17).

Treatments	Initial available P_2O_5 (kg ha^{-1})	Addition of P_2O_5 through fertilizer (kg ha^{-1})	Total P_2O_5 (kg ha^{-1})	Crop uptake of P_2O_5 (kg ha^{-1})	Expected balance P_2O_5 (kg ha^{-1})	Actual available P_2O_5 (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	19.67	0.00	20.16	26.24	-6.08	13.67	19.75
T_2-100% RDF-CF	59.33	62.50	117.59	37.56	80.03	64.33	-15.70
T_3-100% RDF-CF 4 DI	74.43	62.50	127.84	42.49	85.36	76.67	-8.69
T_4-100% RDF-CF 8 DI	63.15	62.50	124.74	40.35	84.39	79.33	-5.06
T_5-100% RDF-WSF 4 DI	64.42	62.50	121.92	56.53	65.39	83.54	18.15
T_6-50% RDF-WSF 4 DI	42.65	31.25	68.90	43.07	25.83	43.50	17.67
T_7-30% RDF-WSF 4 DI	36.91	18.75	50.66	38.25	12.41	37.67	25.25
T_8-100% RDF-WSF 8 DI	63.39	62.50	120.89	57.61	63.29	80.77	17.48
T_9-50% RDF-WSF 8 DI	40.93	31.25	67.18	42.15	25.03	41.67	16.64
T_{10}-30% RDF-WSF 8 DI	33.52	18.75	47.27	39.80	7.47	36.84	29.37
T_{11}-100% STCR dose -WSF 4 DI	118.67	92.80	152.97	56.52	96.45	126.67	30.21
T_{12}-50% STCR dose -WSF 4 DI	70.69	52.54	96.83	43.39	53.44	69.33	15.89
T_{13}-30% STCR dose -WSF 4 DI	51.38	33.01	67.64	38.11	29.54	54.85	25.31
T_{14}-100% STCR dose -WSF 8 DI	114.04	93.99	149.52	57.05	92.47	130.75	38.27
T_{15}-50% STCR dose -WSF 8 DI	63.37	53.48	90.95	44.68	46.27	71.43	25.16
T_{16}-30% STCR dose -WSF 8 DI	51.52	33.00	69.14	40.09	29.05	52.43	23.38

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Table 8: Potassium balance in soil as influenced by different approaches, forms, doses and intervals of fertilizer application on rice under aerobic rice-cowpea cropping system (2015-16)

Treatments	Initial available K_2O (kg ha^{-1})	Addition of K_2O through fertilizer (kg ha^{-1})	Total K_2O (kg ha^{-1})	Crop uptake of K_2O (kg ha^{-1})	Expected balance K_2O (kg ha^{-1})	Actual available K_2O (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	212.40	0.00	212.40	89.43	122.97	97.85	-25.12
T_2-100% RDF-CF	203.79	62.50	266.29	139.93	126.36	107.67	-18.69
T_3-100% RDF-CF 4 DI	193.33	62.50	255.83	151.25	104.59	120.00	15.41
T_4-100% RDF-CF 8 DI	223.60	62.50	286.10	142.91	143.19	124.49	-18.70
T_5-100% RDF-WSF 4 DI	234.13	62.50	296.63	189.22	107.41	126.79	19.38
T_6-50% RDF-WSF 4 DI	195.60	31.25	226.85	133.80	93.05	108.14	15.09
T_7-30% RDF-WSF 4 DI	211.80	18.75	230.55	112.45	118.10	106.95	-11.15
T_8-100% RDF-WSF 8 DI	224.60	62.50	287.10	189.32	97.78	129.00	31.22
T_9-50% RDF-WSF 8 DI	217.80	31.25	249.05	138.04	111.01	120.20	9.20
T_{10}-30% RDF-WSF 8 DI	210.33	18.75	229.08	112.63	116.45	112.33	-4.12
T_{11}-100% STCR dose -WSF 4 DI	212.48	68.43	280.92	189.85	91.06	133.10	42.04
T_{12}-50% STCR dose -WSF 4 DI	196.33	38.21	234.54	138.17	96.37	114.75	18.38
T_{13}-30% STCR dose -WSF 4 DI	204.32	21.74	226.06	112.58	113.48	110.17	-3.31
T_{14}-100% STCR dose -WSF 8 DI	205.85	71.71	277.56	193.20	84.36	127.43	43.06
T_{15}-50% STCR dose -WSF 8 DI	206.80	35.62	242.42	134.62	107.80	118.15	10.35
T_{16}-30% STCR dose -WSF 8 DI	213.67	20.35	234.02	112.27	121.75	109.29	-12.46

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Table 9: Potassium balance in soil as influenced by different approaches, forms, doses and intervals of fertilizer application on rice under aerobic rice-cowpea cropping system (2016-17)

Treatments	Initial available K_2O (kg ha^{-1})	Addition of K_2O through fertilizer (kg ha^{-1})	Total K_2O (kg ha^{-1})	Crop uptake of K_2O (kg ha^{-1})	Expected balance K_2O (kg ha^{-1})	Actual available K_2O (kg ha^{-1})	Net gain (+) or Net loss (-) (kg ha^{-1})
T_1-Control	97.85	0.00	104.78	84.85	19.93	63.00	43.07
T_2-100% RDF-CF	107.67	62.50	200.53	127.38	73.15	100.67	27.51
T_3-100% RDF-CF 4 DI	120.00	62.50	171.79	144.43	27.36	110.51	83.15
T_4-100% RDF-CF 8 DI	124.49	62.50	228.60	140.91	87.69	112.30	24.61
T_5-100% RDF-WSF 4 DI	126.79	62.50	211.62	188.56	23.07	121.34	98.27
T_6-50% RDF-WSF 4 DI	108.14	31.25	139.39	132.12	7.27	100.00	92.73
T_7-30% RDF-WSF 4 DI	106.95	18.75	137.96	108.18	29.78	92.35	62.56
T_8-100% RDF-WSF 8 DI	129.00	62.50	201.65	184.08	17.57	107.08	89.50
T_9-50% RDF-WSF 8 DI	120.20	31.25	151.45	132.25	19.20	95.33	76.13
T_{10}-30% RDF-WSF 8 DI	112.33	18.75	139.54	107.91	31.63	90.90	59.27
T_{11}-100% STCR dose -WSF 4 DI	133.10	107.65	237.73	185.77	51.96	127.24	75.28
T_{12}-50% STCR dose -WSF 4 DI	114.75	58.36	173.11	131.70	41.40	92.89	51.49
T_{13}-30% STCR dose -WSF 4 DI	110.17	35.69	142.79	109.25	33.54	97.61	64.07
T_{14}-100% STCR dose -WSF 8 DI	127.43	110.45	236.34	193.45	42.90	123.89	80.99
T_{15}-50% STCR dose -WSF 8 DI	118.15	57.52	175.67	129.65	46.01	104.04	58.03
T_{16}-30% STCR dose -WSF 8 DI	109.29	35.82	145.71	106.71	39.00	107.67	68.66

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizer, CF: Conventional fertilizers, DI: Days of interval, NS: Non significant

Comment [BS14]: Write all the references uniformly as per the prescribed format of journal

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