

## Effect of different fertilizers and approaches on nutrient use efficiency and economics of aerobic rice under aerobic rice-cowpea cropping sequence

### ABSTRACT

A field experiment was undertaken at University of Agricultural Sciences, GKVK, Bengaluru to study the effect of fertigation on yield, nutrient use efficiency and economics of aerobic rice in aerobic rice-cowpea cropping sequence during 2015-16 and 2016-17. Hybrid rice was tested under aerobic condition with 16 treatments replicated thrice in randomized block design. The results indicated that significantly higher grain ( $62.98 \text{ q ha}^{-1}$ ) and straw ( $85.26 \text{ q ha}^{-1}$ ) yield of rice was recorded in 100% STCR dose through WSF at 8 DI. Similarly higher  $\text{NRn}$  ( $3.50 \text{ kg q}^{-1}$ ) and  $\text{NRp}$  ( $0.86 \text{ kg q}^{-1}$ ) of grain production in 100% STCR dose with WSF at 8 DI. On contrary, higher  $\text{NRk}$  of  $2.27 \text{ kg q}^{-1}$  was noticed in 100% STCR with WSF at 4 DI. While higher  $\text{AUE-N}$  ( $32.51 \text{ kg kg}^{-1}$ ),  $\text{AUE-P}$  ( $65.02 \text{ kg kg}^{-1}$ ) and  $\text{AUE-K}$  ( $65.02 \text{ kg kg}^{-1}$ ) were recorded in 30% RDF with WSF at 8 DI. The higher  $\text{ACRE-N}$  (78.60 %) was recorded with 100% RDF with WSF at 8 DI and higher  $\text{ACRE-P}$  (44.40%) was recorded with 30% RDF with WSF at 8 DI. On contrary notably higher  $\text{ACRE-K}$  (132.51%) was recorded in 30% STCR with WSF at 8 DI. However, supplement of 30% STCR dose with WSF at 8 DI obtained notably higher  $\text{IUE-N}$  ( $35.05 \text{ kg kg}^{-1}$ ),  $\text{IUE-P}$  ( $163.27 \text{ kg kg}^{-1}$ ) and  $\text{IUE-K}$  ( $60.11 \text{ kg kg}^{-1}$ ). Significantly higher  $\text{PFP-N}$ ,  $\text{P}$  and  $\text{K}$  (261.23, 522.46 and 522.46, respectively) were recorded in 30% RDF with WSF at 8 DI. Among all treatments, 100% RDF through CF at 4 DI found significantly higher B: C ratio (2.74) during both years of pooled data.

**Key words:** Aerobic rice, cowpea, STCR, WSF, CF, Cost of cultivation, B: C ratio

### INTRODUCTION

In India, rice is traditionally grown in standing water using flood irrigation, which accounts for a large amount of water use in rice production, typical irrigation rates of average  $1200 \text{ mm ha}^{-1} \text{ yr}^{-1}$  and in extremely dry years could exceed 1400-1500 mm (Lal *et al.*, 2013). With a production output of 129.4 million metric tons and an average productivity of 2.80 metric tons per hectare, India plays a pivotal role in global rice production hectare (Indiastat, 2021-22). The diminishing water resources and rising water costs pose a threat to the conventional practice of puddled transplanted rice farming (Maraseni *et al.*, 2018 and Umilsinghet *et al.*, 2024).

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In many states the utilization of surface and groundwater has peaked and unless we adopt water-saving technologies sustainable agriculture will become increasingly challenging in the future. Improved water management is crucial for sustainable rice cultivation. Various strategies are being actively pursued to minimize the water requirements of rice production. These include adopting practices like alternate wetting and drying by implementing the system of rice intensification (SRI) and transitioning to aerobic rice cultivation. There is need for increased water productivity and in recent developments demonstrated that rice can also be grown in dry soils under non-flooded conditions called “aerobic rice”. Among the water saving technologies, the aerobic rice cultivation saved more water and hence it improves water use efficiency and water productivity of rice (Govindan and Grace, 2012; Umilsinghet *al.*, 2023).Fertigation provides the most effective way of supplying nutrients to the plant root and greatly reduces pollution risk to the environment, like decrease in methane gas emission under drip fertigation in aerobic paddy field (Adekoya *et al.*, 2014). This would be the boon for future green revolution and food security through water and energy security.

Future, the fertilizer will be one of the costliest inputs in agriculture and the use of right amount of fertilizer nutrient is fundamental for farm profitability and environmental protection. Thus, fertilizer feeds the world through feeding the soils and in turn plants, and if world is not to go hungry, fertilizers will continue to play a pivotal role in food grain production. Worldwide mineral fertilizer nutrient use is expected to increase from 175 million tons in 2015 to 199 million tons in 2030 (FAO, 2000). Traditionally, to determine the optimum fertilizer doses, the most commonly used method is to apply fertilizer on the basis of soil testbased fertilizer recommendation which is commonly followed in the soil testing laboratories throughout the country, called as soil test laboratory/ low-medium-high approach. However, most scientific and appropriate method is soil test crop response (STCR) targeted yield approach where fertilizer application is by incorporating soil test values, nutrient requirement of the crop, contribution of nutrients from soil, manures, fertilizers for specific yield targets (Pandu *et al.*, 2022).

The important pulses grown in India are red gram, green gram, black gram, cowpea, moth bean, horse gram, peas *etc.* Among arid legumes, cowpea (*Vigna unguiculata*L.) is of immense importance, as it is a multipurpose grain legume extensively cultivated in arid and semiarid tropics. In India, it has been cultivated from very early times for human and animal consumption. Fodder cowpea can profitably be grown as a summer crop in rice fallow of sandy loam soils

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where water is not sufficiently available to raise a subsequent crop. In a cropping system, response of the component crop is influenced by the preceding crop and inputs applied to them (Patidar and Mali, 2002).

Drip irrigation facilitates maximal water and nutrient efficiency by reducing the active root zone, and thus minimizing the wetting area. Adding fertilizer to drip irrigation reduces the costs associated with irrigation and fertilizer application. Additionally, fertigation minimizes the losses of nutrients through leaching. Fertigation of water-soluble fertilizer had higher concentration of available plant nutrients in top layer over soil application of normal fertilizer (Hebbar *et al.*, 2004). Losses and fixation was minimal when applied in small quantity with a more number of splits which ultimately resulted in higher fertilizer use efficiency compared to conventional method where application of fertilizers at a fixed dose with less number of splits which may attribute for more losses of nutrients through various means (Jayanthi *et al.*, 2023).

Greater N-use efficiency in rice can be achieved by using water-soluble N sources with suitable varieties, improving timing and application methods and better incorporation of basal N fertilizer application without standing water (Keerthi *et al.*, 2020). Trickle fertigation permits application of nutrients directly at the site of high concentration of active roots. Since nutrients are applied to a limited soil volume, the fertilizer use efficiency is also high. On the other hand, conventional fertilization especially on light soils may cause huge nutrient losses through leaching, percolation and volatilization (Rekha *et al.*, 2015). Drip fertigation also enables accurate adjustment of water and nutrient supplies to meet the crop requirements. Taking these points into account an investigation was carried out to evaluate the effects of drip fertigation on yield, nutrient use efficiency and economics of aerobic rice.

## **MATERIAL AND METHODS**

Hybrid rice (KRH-4) was used as the test crop in this experiment, which involved sixteen treatments that were reproduced three times during *Kharif* 2015 and 2016. The investigation also examined the residual effects of these treatments on cowpea crop (KM-5), which was grown at ZARS, GKVK, Bangalore, throughout the summer seasons of 2016 and 2017. In an RCBD design, two years' worth of pooled data from an aerobic rice crop were gathered and examined. Treatments comprised of T<sub>1</sub>:Control (without NPK fertilizers), T<sub>2</sub>:100% RDF-Conventional fertilizers through soil application as per PoP, T<sub>3</sub>:100% RDF-Conventional fertilizers through fertigation at 4 days interval (DI), T<sub>4</sub>:100% RDF-Conventional fertilizers through fertigation at 8

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days interval, T<sub>5</sub>:100% RDF-Water soluble fertilizers through fertigation at 4 days interval, T<sub>6</sub>:50% RDF-Water soluble fertilizers through fertigation at 4 days interval, T<sub>7</sub>:30% RDF-Water soluble fertilizers through fertigation at 4 days interval, T<sub>8</sub>:100% RDF-Water soluble fertilizers through fertigation at 8 days interval, T<sub>9</sub>:50% RDF-Water soluble fertilizers through fertigation at 8 days interval, T<sub>10</sub>:30% RDF-Water soluble fertilizers through fertigation at 8 days interval, T<sub>11</sub>:100% STCR-Water soluble fertilizers through fertigation at 4 days interval, T<sub>12</sub>:50% STCR-Water soluble fertilizers through fertigation at 4 days interval, T<sub>13</sub>:30% STCR-Water soluble fertilizers through fertigation at 4 days interval, T<sub>14</sub>:100% STCR-Water soluble fertilizers through fertigation at 8 days intervals, T<sub>15</sub>:50% STCR-Water soluble fertilizers through fertigation at 8 days intervals and T<sub>16</sub>:30% STCR-Water soluble fertilizers through fertigation at 8 days intervals.

In accordance with the package of practices for hybrid rice, 20 days prior to sowing, the recommended dosage of farm yard manure (10 t ha<sup>-1</sup>) was added to the soil. ZnSO<sub>4</sub> (20 kg ha<sup>-1</sup>) and N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O (125:62.5:62.5 kg ha<sup>-1</sup>) were applied in accordance with the treatments, with the exception of the absolute control treatment. In treatment T<sub>2</sub>, 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. N was applied in three split doses: 50% as basal, the remaining 50% nitrogen was top dressed in two equal splits during active tillering and before panicle initiation stage. From T<sub>3</sub> to T<sub>16</sub> treatments, the basal dose of fertilizers was administered at the time of planting at 30%, 50%, and 30% (N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, respectively). For T<sub>3</sub> and T<sub>4</sub> treatments, conventional fertilizers were used to supply the remaining 70%, 50%, and 70% of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, respectively, at intervals of 4 (15 times) and 8 (8 times) days after fertigation. Additionally, the remaining 70%, 50%, and 70% of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O for the water soluble fertilizer treatments (T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>11</sub>, T<sub>12</sub> & T<sub>13</sub> and T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub>, T<sub>14</sub>, T<sub>15</sub> & T<sub>16</sub>) were achieved using various grades of water soluble fertilizers, such as 19:19:19 (19 all), Mono Potassium Phosphate (MPP), Mono Ammonium Phosphate (MAP), Sulphate of Potash (SOP), and Calcium nitrate (CN), at intervals of 4 (15 times) and 8 (8 times) days of fertigation. Using a ventilatory system, the fertigation process was carried out for each plot according to the treatments, commencing 20 days after sowing and continuing until 80 days later, or the panicle initiation stage. A standard irrigation schedule was followed for every treatment. Following the harvest of aerobic rice in both years, the ground was

prepared for summer planting of cowpea, a crop chosen to test the long-term effects of water-soluble fertilizer fertigation.

Before the experiment was conducted, the first soil samples were taken from each plot independently. The soil samples were then air dried, ground into a powder, sieved, and kept in plastic storage containers. Additionally, analysis was done using conventional protocols for several physical and chemical parameters. Likewise, following the aerobic rice harvest, soil samples from both years' plots were gathered, and examination was carried out in accordance with conventional protocols. The texture of the experimental field soil is sandy clay loam, and its soil reaction was neutral (6.72). The soil's initial fertility status revealed low organic carbon (OC) content, low available nitrogen (N) content, medium available P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O (21.59, 21.98, and 210.43 kg ha<sup>-1</sup>, respectively), sufficient amounts of extracellular calcium and magnesium (3.66-3.63 [cmol (p+) kg<sup>-1</sup>], respectively), and available sulfur (17.60 ppm) content. DTPA extractable micronutrients viz., (Fe-18.28, Zn-1.65, Mn-23.91 and Cu-0.61 ppm) content in the soil was above critical levels.

The quantity of fertilizers for STCR treatments (T<sub>11</sub> to T<sub>16</sub>) required for a yield of 80 q ha<sup>-1</sup> were determined (Table 1) by using STCR targeted yield equation developed at ZARS, V.C. Farm, Mandya (Prakash et al., 2007) and it is as follows.

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

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

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

Where,

T = Targeted yield (q ha<sup>-1</sup>) i.e. 80 q ha<sup>-1</sup>

FN = Fertilizer nitrogen (kg ha<sup>-1</sup>)

FP<sub>2</sub>O<sub>5</sub> = Fertilizer phosphorus (kg ha<sup>-1</sup>)

FK<sub>2</sub>O = Fertilizer potassium (kg ha<sup>-1</sup>)

OM = Organic manure (FYM) (kg ha<sup>-1</sup>)

SN, SP<sub>2</sub>O<sub>5</sub> and SK<sub>2</sub>O are initial available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg ha<sup>-1</sup>, 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 <sup>-1</sup> )					
	2015-16			2016-17		
	N	P	K	N	P	K

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T <sub>1</sub> -Control	0.00	0.00	0.00	0.00	0.00	0.00
T <sub>2</sub> -100% RDF-CF	125.00	62.50	62.50	125.00	62.50	62.50
T <sub>3</sub> -100% RDF-CF 4 DI	125.00	62.50	62.50	125.00	62.50	62.50
T <sub>4</sub> -100% RDF-CF 8 DI	125.00	62.50	62.50	125.00	62.50	62.50
T <sub>5</sub> -100% RDF-WSF 4DI	125.00	62.50	62.50	125.00	62.50	62.50
T <sub>6</sub> -50% RDF-WSF 4DI	62.50	31.25	31.25	62.50	31.25	31.25
T <sub>7</sub> -30% RDF-WSF 4 DI	37.50	18.75	18.75	37.50	18.75	18.75
T <sub>8</sub> -100% RDF-WSF 8 DI	125.00	62.50	62.50	125.00	62.50	62.50
T <sub>9</sub> -50% RDF-WSF 8 DI	62.50	31.25	31.25	62.50	31.25	31.25
T <sub>10</sub> -30% RDF-WSF 8 DI	37.50	18.75	18.75	37.50	18.75	18.75
T <sub>11</sub> -100% STCR dose -WSF 4 DI	154.61	118.50	68.43	196.66	92.80	107.65
T <sub>12</sub> -50% STCR dose -WSF 4 DI	76.74	58.60	38.21	106.15	52.54	58.36
T <sub>13</sub> -30% STCR dose -WSF 4 DI	45.87	35.21	21.74	65.87	33.01	35.69
T <sub>14</sub> -100% STCR dose -WSF 8 DI	148.08	116.71	71.71	200.73	93.99	110.45
T <sub>15</sub> -50% STCR dose -WSF 8 DI	74.98	59.02	35.62	108.10	53.48	57.52
T <sub>16</sub> -30% STCR dose -WSF 8 DI	44.23	34.84	20.35	66.72	33.00	35.82

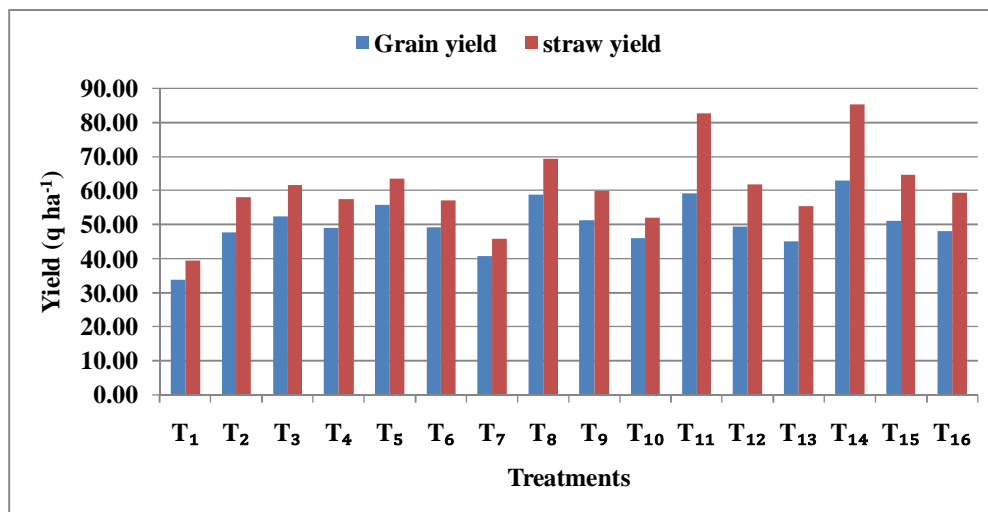
## RESULTS AND DISCUSSION

### Grain and straw yield of aerobic rice

Significantly higher grain (62.98 q ha<sup>-1</sup>) and straw (85.26 q ha<sup>-1</sup>) yield of rice were recorded in treatment which received fertigation with 100% STCR dose through water soluble fertilizers at 8 DI (Fig 1). This may be ascribed to its complete solubility of WSF and 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 and Parmanand (2018).

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

#### Nutrient requirement of N, P and K by rice

Significantly higher NRn ( $3.50 \text{ kg q}^{-1}$ ) of aerobic rice grain production in 100% STCR dose with WSF at 8 DI. The treatment with 100% STCR dose with WSF 8 DI has recorded significantly higher NRp ( $0.86 \text{ kg q}^{-1}$ ). Significantly higher NRk of  $2.27 \text{ kg q}^{-1}$  was noticed in 100% STCR with WSF at 4 DI (Table 2). This might be due to more uptake of nutrients with water soluble fertilizers because of their complete solubility, availability and efficiency as compared to conventional fertilizers in chilli crop (Veeranna, 2000).

**Table 2: Effect of different approaches, forms, doses and intervals of fertilizer application on nutrient requirement of N, P and K of rice grain production under aerobic rice-cowpea cropping sequence.**

Treatments	NR	PR	KR
	(kg q <sup>-1</sup> )		
T <sub>1</sub> -Control	3.06	0.63	1.69
T <sub>2</sub> -100% RDF-CF	2.97	0.63	1.95
T <sub>3</sub> -100% RDF-CF 4 DI	3.14	0.64	1.97
T <sub>4</sub> -100% RDF-CF 8 DI	3.22	0.67	1.87
T <sub>5</sub> -100% RDF-WSF 4 DI	3.49	0.73	1.91
T <sub>6</sub> -50% RDF-WSF 4 DI	2.94	0.64	1.76
T <sub>7</sub> -30% RDF-WSF 4 DI	2.91	0.62	1.78

T <sub>8</sub> -100% RDF-WSF 8 DI	3.43	0.73	1.94
T <sub>9</sub> -50% RDF-WSF 8 DI	2.91	0.66	1.91
T <sub>10</sub> -30% RDF-WSF 8 DI	2.89	0.65	1.74
T <sub>11</sub> -100% STCR dose -WSF 4 DI	3.48	0.80	2.27
T <sub>12</sub> -50% STCR dose -WSF 4 DI	2.92	0.67	1.81
T <sub>13</sub> -30% STCR dose -WSF 4 DI	2.88	0.66	1.90
T <sub>14</sub> -100% STCR dose -WSF 8 DI	3.50	0.86	2.24
T <sub>15</sub> -50% STCR dose -WSF 8 DI	3.03	0.73	1.89
T <sub>16</sub> -30% STCR dose -WSF 8 DI	2.92	0.72	1.87
<b>S Em ±</b>	<b>0.16</b>	<b>0.04</b>	<b>0.14</b>
<b>CD at 5%</b>	<b>0.45</b>	<b>0.11</b>	<b>0.39</b>

RDF: Recommended dose of fertilizer, STCR: Soil test crop response, WSF: Water soluble fertilizers,

CF: Conventional fertilizers, DI: Days interval, NS: Non significant

#### **Agronomic use efficiency of N, P and K in rice**

Significantly higher (32.51 kg kg<sup>-1</sup>) AUE-N was recorded in 30% RDF with WSF at 8 DI. Significantly higher AUE-P (65.02 kg kg<sup>-1</sup>) in 30% RDF with WSF at 8 DI. The treatment 30% RDF with WSF at 8 DI has recorded significantly higher AUE-K of 65.02 kg kg<sup>-1</sup> (Table 3). The higher use efficiency of nutrients under fertigation might be ascribed to increase the availability of nutrients to the plants directly near the root zone. Singandhupeet *et al.* (2003) revealed that, in drip irrigation method, frequent application of nitrogen as urea followed by the formation of NH<sub>4</sub><sup>+</sup>, its adsorption on soil clay minerals for a longer period followed by a gradual formation of nitrate nitrogen increased fertilizer use efficiency. Dakshina Murthy *et al.* (2015) also explained agronomic efficiency of N, P and K was progressively increased in rice with incremental doses of respective nutrients.

#### **Apparent crop recovery efficiency (ACRE) of N, P and K in rice**

The higher ACRE-N was recorded (78.60%) in treatment with 100% RDF+WSF at 8 DI through fertigation and data is presented in Table 3. Significantly higher ACRE-P (44.40%) was recorded in 30% RDF with WSF at 8 DI. Significantly higher ACRE-K (132.51%) was recorded in 30% STCR with WSF at 8 DI (Table 3). This may be due to better availability of nutrients and concomitant utilization by the crop with incremental levels of N, P and K. This is an indication of the fact that recovery efficiency of the incremental doses is good at initial increments and shows the scope for increased levels of respective nutrients. These results are in close agreement with those of Upadhyay and Patel (1992). The increased ACRE-P was noticed in WSF applied at lower doses as compared to higher dose with conventional fertilizers which might be due to

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higher availability of P nutrient in soil through supply of P from completely soluble form from the water soluble fertilizers also supply of P from mineralization of FYM.

**Table 3: Effect of different approaches, forms, doses and intervals of fertilizer application on agronomic use efficiency and apparent crop recovery efficiency of N, P and K in rice under aerobic rice-cowpea cropping sequence.**

Treatments	AUE-N	AUE-P	AUE-K	ACRE-N	ACRE-P	ACRE-K
	(kg kg <sup>-1</sup> )			(%)		
T <sub>1</sub> -Control	0.00	0.00	0.00	0	0	0
T <sub>2</sub> -100% RDF-CF	11.13	11.13	11.13	29.97	14.37	56.45
T <sub>3</sub> -100% RDF-CF 4 DI	14.90	14.90	14.90	47.70	20.13	73.13
T <sub>4</sub> -100% RDF-CF 8 DI	12.24	12.24	12.24	43.28	18.84	56.02
T <sub>5</sub> -100% RDF-WSF 4 DI	17.58	17.58	17.58	72.85	30.82	78.88
T <sub>6</sub> -50% RDF-WSF 4 DI	24.69	24.69	24.69	66.59	33.13	95.19
T <sub>7</sub> -30% RDF-WSF 4 DI	18.61	18.61	18.61	40.36	20.72	81.12
T <sub>8</sub> -100% RDF-WSF 8 DI	19.98	19.98	19.98	78.60	34.64	91.19
T <sub>9</sub> -50% RDF-WSF 8 DI	27.93	27.93	27.93	73.39	39.78	131.44
T <sub>10</sub> -30% RDF-WSF 8 DI	32.51	32.51	32.51	75.70	44.40	119.91
T <sub>11</sub> -100% STCR dose -WSF 4 DI	14.53	14.53	14.53	59.18	24.68	90.57
T <sub>12</sub> -50% STCR dose -WSF 4 DI	17.08	17.08	17.08	45.58	21.70	72.87
T <sub>13</sub> -30% STCR dose -WSF 4 DI	20.61	20.61	20.61	48.23	25.14	110.90
T <sub>14</sub> -100% STCR dose -WSF 8 DI	17.08	17.08	17.08	69.51	31.31	96.02
T <sub>15</sub> -50% STCR dose -WSF 8 DI	19.27	19.27	19.27	58.72	28.90	93.09
T <sub>16</sub> -30% STCR dose -WSF 8 DI	26.80	26.80	26.80	69.82	39.82	132.51
<b>SEm ±</b>	<b>5.20</b>	<b>5.20</b>	<b>5.20</b>	<b>9.15</b>	<b>6.31</b>	<b>14.63</b>
<b>CD at 5%</b>	<b>14.70</b>	<b>14.70</b>	<b>14.70</b>	<b>ACRE-N</b>	<b>ACRE-P</b>	<b>ACRE-K</b>

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

#### Internal Utilization Efficiency of N, P and K

Significantly higher IUE-N in aerobic rice (35.05 kg kg<sup>-1</sup>) was recorded in 30% STCR dose with WSF at 8 DI. The treatment with 30% RDF through water soluble fertilizers at 4 DI of fertigation was recorded significantly higher (163.27 kg kg<sup>-1</sup>) IUE-P. The control treatment was recorded significantly higher (60.11 kg kg<sup>-1</sup>) IUE-K (Table 4). Prakash *et al.* (2021) concluded that the utilization efficiency of N, P and K was higher with no nutrient applied (43.04%, 207.66% and 41.22%, respectively) than other treatments. Increase in fertilizer levels decreased the utilization efficiency in rice (Table 4).

#### Partial Factor Productivity on N, P and K

Significantly higher (261.23) PFP-N was recorded in 30% RDF with WSF at 8 DI than other treatments. The treatment with 30% RDF with WSF at 8 DI was recorded significantly

higher (522.46) PFP-P in aerobic rice than other treatments (Table 4). Significantly higher PFP-K was noticed (522.46) in 30% RDF with WSF at 8 DI than other remaining treatments (Table 4). This increased PFP in the present investigation due to balanced application of nutrients, increased nutrient uptake and utilization of indigenous nutrients, and by increasing the efficiency with which applied nutrients are taken up by the crop and utilized to produce grain (Singh *et al.*, 2008). This may be due to synchronizing split NPK application with crop demand enhanced agronomic efficiency, recovery efficiency and partial factor productivity of NPK. Maximum fertilizer nutrient recovery was attained when more nutrients were available to plants (Cassman *et al.*, 2002). Application of recommended dose of N in 3-split doses resulted in more AE and RE than 2-split doses in wheat (Ratanoo *et al.* 2016).

**Table 4: Effect of different approaches, forms, doses and intervals of fertilizer application on N, P and K internal utilization efficiency and partial factor productivity in rice under aerobic rice-cowpea cropping sequence.**

Treatments	IUE-N	IUE-P	IUE-K	PFP-N	PFP-P	PFP-K
	(kg kg <sup>-1</sup> )					
T <sub>1</sub> -Control	32.92	161.42	60.11	0	0	0
T <sub>2</sub> -100% RDF-CF	33.96	158.43	52.11	84.58	169.15	169.15
T <sub>3</sub> -100% RDF-CF 4 DI	32.31	156.61	51.29	91.23	182.45	182.45
T <sub>4</sub> -100% RDF-CF 8 DI	31.23	150.87	53.83	85.26	170.53	170.53
T <sub>5</sub> -100% RDF-WSF 4 DI	28.75	139.55	52.76	95.47	190.95	190.95
T <sub>6</sub> -50% RDF-WSF 4 DI	34.09	156.88	57.08	170.04	340.09	340.09
T <sub>7</sub> -30% RDF-WSF 4 DI	34.55	163.27	56.89	230.86	461.72	461.72
T <sub>8</sub> -100% RDF-WSF 8 DI	29.29	138.53	51.76	102.36	204.71	204.71
T <sub>9</sub> -50% RDF-WSF 8 DI	34.42	152.86	52.65	177.77	355.54	355.54
T <sub>10</sub> -30% RDF-WSF 8 DI	35.05	156.47	58.22	261.23	522.46	522.46
T <sub>11</sub> -100% STCR dose -WSF 4 DI	28.82	126.23	45.50	82.41	134.95	171.95
T <sub>12</sub> -50% STCR dose -WSF 4 DI	34.34	149.43	55.25	126.03	199.93	243.34
T <sub>13</sub> -30% STCR dose -WSF 4 DI	34.99	152.49	53.33	188.77	294.18	380.34
T <sub>14</sub> -100% STCR dose -WSF 8 DI	28.66	117.85	45.68	87.69	141.55	172.56
T <sub>15</sub> -50% STCR dose -WSF 8 DI	33.18	137.37	52.99	131.64	205.87	266.59
T <sub>16</sub> -30% STCR dose -WSF 8 DI	34.44	139.37	54.20	204.90	316.24	423.92
<b>SEm ±</b>	<b>1.71</b>	<b>7.88</b>	<b>3.44</b>	<b>05.78</b>	<b>10.24</b>	<b>14.19</b>
<b>CD at 5%</b>	<b>4.85</b>	<b>22.29</b>	<b>9.71</b>	<b>16.33</b>	<b>28.96</b>	<b>40.12</b>

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

#### Cost of cultivation

Significantly higher cost of cultivation (Rs.76,861) was recorded in treatment received 100% RDF with WSF at 4 DI than other treatments except 100% RDF with WSF at 8 DI, which

was statistically (Rs.76,361) on par (Table 5). However lower cost (Rs.27,990) of cultivation was noticed in control plot.

#### **Gross returns**

Significantly higher gross returns (Rs.1,38,753) has registered in 100% STCR with WSF at 8 DI than other treatments but, it was statistically on par with 100% STCR dose -WSF 4 DI (Rs.1,30,350) and 100% RDF-WSF 8 DI (Rs.1,27,935.00) treatment. However, lower gross return was noticed in control plot (Rs.73,522) is depicted in Table 6.

#### **Net returns**

Totally 16 different treatments combinations were accommodated in the present investigation, significantly higher net returns of Rs.72,484 was recorded in 100% RDF with conventional fertilizer at 4 DI than other treatments (Table 5). However, lower net return of Rs.40,104 was noticed in 30% RDF with WSF at 4 DI treatment.

#### **Benefit cost ratio (B:C ratio)**

In the present investigation, significantly higher B: C ratio (2.74) was recorded in 100% RDF with conventional fertilizer at 4 DI than other treatments except Control, 100% RDF-CF and 100% RDF-CF 4 DI, which were statistically on par (Table 5). However, lower B:C ratio was noticed (1.58) in 100% RDF with WSF at 4 DI plot.

Kavitha *et al.* (2007) reported that though the yield was higher with WSF plots, the benefit cost ratio was less mainly due to high cost of special fertilizers in drip fertigated tomato. However, the yield and gross income was high in the fertigated plots, due to higher uptake and higher nutrient use efficiency of costly fertilizers, which obtain very meagre difference of B: C ratio when compared with drip irrigated with soil application of 100% RDF. Thus the additional expenditure towards the water soluble fertilizers were well compensated though greater additional income. Similar results were observed by Veeranna (2000) where 80% of the soluble fertilizers got higher yield with lower B:C ratio due to higher prices for WSF.

Tahmina *et al.* (2022) reported that combined application of organic and inorganic fertilizers significantly influenced the rice yield, nutrient uptake, and their subsequent use efficiencies, contents of organic carbon. Recovery, agronomic, and physiological efficiency of N, P, and K showed significant differences among the treatments in rice cultivation. The recovery efficiency (RE) of nitrogen was found to be significantly higher in the treatments comprising of the organic and inorganic fertilizers (56-58%) over the RD and farmers practice.

**Table 5: Effect of different approaches, forms, doses and intervals of fertilizer application on cost of cultivation and gross returns of rice growing under aerobic rice-cowpea cropping system**

Treatments	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B: C ratio
T <sub>1</sub> -Control	27990.00	73522.33	45532.33	2.63
T <sub>2</sub> -100% RDF-CF	40919.10	104121.50	63202.40	2.54
T <sub>3</sub> -100% RDF-CF 4 DI	41619.10	114103.33	72484.23	2.74
T <sub>4</sub> -100% RDF-CF 8 DI	41119.10	106821.75	65702.65	2.60
T <sub>5</sub> -100% RDF-WSF 4 DI	76861.20	121088.33	44227.13	1.58
T <sub>6</sub> -50% RDF-WSF 4 DI	56480.60	107023.17	50542.56	1.90
T <sub>7</sub> -30% RDF-WSF 4 DI	48328.36	88432.08	40103.72	1.83
T <sub>8</sub> -100% RDF-WSF 8 DI	76361.20	127935.00	51573.80	1.68
T <sub>9</sub> -50% RDF-WSF 8 DI	55980.60	111490.83	55510.23	1.99
T <sub>10</sub> -30% RDF-WSF 8 DI	47828.36	99781.92	51953.56	2.09
T <sub>11</sub> -100% STCR dose-WSF 4 DI	75007.38	130349.92	55342.54	1.75
T <sub>12</sub> -50% STCR dose-WSF 4 DI	56662.46	107836.00	51173.54	1.91
T <sub>13</sub> -30% STCR dose-WSF 4 DI	48587.96	98262.67	49674.70	2.03
T <sub>14</sub> -100% STCR dose-WSF 8 DI	74664.32	138752.83	64088.51	1.87
T <sub>15</sub> -50% STCR dose-WSF 8 DI	56031.39	111828.33	55796.94	2.01
T <sub>16</sub> -30% STCR dose-WSF 8 DI	47956.64	105114.67	57158.03	2.20
<b>SEm ±</b>	<b>255.39</b>	<b>5464.96</b>	<b>5444.40</b>	<b>0.11</b>
<b>CD at 5%</b>	<b>721.98</b>	<b>15449.29</b>	<b>15391.18</b>	<b>0.32</b>

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

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