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Residual Effect of Water Soluble Fertilizers on Productivity and Nutrients Uptake of Cowpea in Aerobic Rice-cowpea Cropping Sequence under Fertigaton

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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 was under taken at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka state, India to study the residual effect of fertigation of water soluble fertilizers on productivity and nutrients uptake of cowpea under aerobic rice-cowpea cropping sequence during *Kharif* 2015-16 and 2016-17 with 16 treatments replicated thrice in randomized block design. Significantly higher plant height (58.47 cm), number of branches plant^{-1} (11.71) and total dry matter accumulation plant^{-1} (70.60 g) were recorded in fertigation with 100% RDF through water soluble fertilizer at 8 DI. Likely, similar treatment 100% RDF through water soluble fertilizer at 8 DI was recorded significantly higher number of pods plant^{-1} (16.58), pod length (16.67 cm), seeds per pod (16.10), test weight (11.93 g), seed yield (12.94 q ha^{-1}) and haulm yield (26.17 q ha^{-1}). While higher total uptake of N, P and K by cowpea (68.94, 14.67 and 61.39 kg N, P and K ha^{-1}, respectively) was recorded in 100% RDF through water soluble fertilizers at 4 DI (T_5) than all other treatments. 100% RDF through WSF at 8 DI (T_8) was recorded notably higher total Ca, Mg and S uptake by cowpea (50.71, 24.71 and 12.09 kg Ca, Mg and S ha^{-1}, respectively). Significantly higher uptake of total Fe, Zn and Cu by cowpea crop (680.23, 91.30 and 38.27 g ha^{-1}, respectively) was recorded with 100% RDF through water soluble fertilizers at 8 DI (T_8). Total uptake of Mn was recorded higher by cowpea was observed (181.67 g ha^{-1}) in 100% STCR dose through water soluble fertilizers at 4 DI (T_{11}).

Keywords: STCR; RDF; WSF; CF; cowpea; uptake of nutrients.

1. INTRODUCTION

Rice-cowpea cropping system is one of the important and economically remunerative system practiced in India. But, cowpea is hardy crops come up well with low fertility soil or residual nutrients applied for the previous crops due symbiotic association with rhizobium microorganisums survive in their roots. Further, Cowpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 130 kg N ha^{-1} from atmosphere they can fix the atmospheric N to plant available form. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility. They are mainly grown in the warm climates since they require warm soil temperatures between 27℃ and 35℃ for good establishment [1]. They are adapted to a wide variety of soils from heavy to light textured and from the humid tropics to the semi-arid tropics [2]. For efficient irrigation management in the field, water lost from plant and soil play an important role by providing information for accurately determination of crop-water requirements and irrigation schedule [3]. Based on the above discussion the present study was initiated by integrated use of organic fertilizers along with inorganic fertilizers either through WSF were applied through different approaches for aerobic rice and their residual effect of fertigation of water soluble fertilizers on growth and yield of cowpea and total nutrients uptake by cowpea under aerobic rice-cowpea cropping sequence under aerobic rice-cowpea cropping sequence.

2. MATERIALS 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 analysed 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 days interval, T_5: 100% RDF-Water soluble fertilizers through fertigation at 4 days interval, T_6: 50% RDF-Water soluble fertilizers through fertigation at 4 days interval, T_7: 30% RDF-Water soluble fertilizers through fertigation at 4 days interval, T_8: 100% RDF-Water soluble fertilizers through fertigation at 8 days interval, T_9: 50% RDF-Water soluble fertilizers through fertigation at 8 days interval, T_{10}: 30% RDF-Water soluble fertilizers through fertigation at 8 days interval, T_{11}: 100% STCR-Water soluble fertilizers through fertigation at 4 days interval, T_{12}: 50% STCR-Water soluble fertilizers through fertigation at 4 days interval,

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

For hybrid rice, as per the package of practice the recommended dose of farm yard manure at 10 t ha^{-1} was incorporated into the soil 20 days before sowing, $ZnSO_4$ at 20 kg ha^{-1} and N, P_2O_5, K_2O at 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 were applied at the time of sowing at 30%, 50% and 30% (N, P_2O_5 and K_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 and K_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}) the remaining 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 ventury system starting from 20 days after sowing and continued up to 80days 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 suceeding crop to check the residual effect of fertigation of water soluble fertilizers.

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 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. After the harvest of previous hybrid rice crop under aerobic condition, the plots were tilled individually and stubbles were removed to bring the soil to fine tilth. Leveling within each plot was done to facilitate uniform drip irrigation.

Cowpea (*var.*KM-5) was used for experimentation during summer season to study the residual effect of different doses and forms of fertilizers along with FYM after the harvest of the hybrid rice crop at *kharif*. The cowpea seeds were treated with Rhizobium and PSB as per the package of practice (PoP). The furrows were opened at 45cm and seeds were placed at 10cm distance within the rows at a depth of 5cm with a seed rate of 25 kg ha^{-1} and covered with soil (Table 1).

Table 1. Treatments imposed for succeeding cowpea crop

Crop	Cowpea
Variety	KM-5
Spacing	45 cm x 10 cm
Design	RCBD
Season	Summer 2016 and 2017
Plot size	4.50 m x 4.20 m=18.9 m^2 (gross plot size)
No of Treatments	16
No of replications	3
NPK fertilizers	No fertilizers and manures were applied for residual cowpea crop

2.1 Statistical Analysis and Interpretation of Data

Data obtained in this experiment were subjected to statistical analysis adopting Fisher's method of 'analysis of variance' as out lined by Gomez and Gomez [4]. The level of significance used in 'F' test was given at five per cent.

3. RESULTS AND DISCUSSION

3.1 Growth Parameter of Cowpea

The results indicated that the growth (Table 2), significantly higher plant height (58.47 cm), number of branches plant^{-1} (11.71) and total dry matter accumulation plant^{-1} (70.60 g). This was attributed to complete soluble and easily available water-soluble fertilizer had higher concentration of available plant nutrients at top layer over normal fertilizer [5], thus results in higher uptake of NPK nutrients by residual cowpea with increase in higher growth parameters.

3.2 Yield Parameters of Cowpea

Significantly higher number of pods plant^{-1} (16.58), pod length (16.67 cm), seeds pod^{-1} (16.10), test weight (11.93 g) were recorded in fertigation with 100% RDF through water soluble fertilizer at 8 DI. 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 water soluble fertilizer at 8 DI (Table 3). This may be due to higher nutrients availability at 100% fertilizer dose perhaps, higher uptake of nutrients *viz*., N, P and K promotes the higher photosynthetic efficiency resulted in increased dry matter was usually associated with higher number of branches plant^{-1} which led to greater accumulation of photosynthesis, which might have led to formation of more number of pods plant^{-1} and number of seeds pod^{-1}. Similarly, Okeleye and Okelana [6] recorded higher magnitude of yield components may be due to greater accumulation of photosynthesis. Similar findings were also observed in chickpea by Shreenivas et al., 2015 and Nitin et al. [7].

3.3 Seed and Haulm Yield of Cowpea

Fertigation with 100% RDF through water soluble fertilizers at 8 DI (T_8) treatment was recorded significantly higher seed yield (12.94 q ha^{-1}) compared to T_1,T_2,T_3,T_{13} and T_{16} treatments and all other remaining treatments were statistically on par at harvest. However, significantly lower seed yield of 7.57 q ha^{-1} was recorded in absolute control treatment (T_1) without NPK and FYM application. The treatment which received fertigation with 100% RDF through water soluble fertilizers at 8 DI (T_8) has recorded significantly higher haulm yield (26.17 q ha^{-1}) over T_1,T_2,T_3,T_4,T_7,T_{10},T_{13} and T_{16} treatments and all other remaining treatments were statistically on par. However, significantly lower haulm yield (14.86 q ha^{-1}) was recorded in absolute control treatment (T_1), without NPK and FYM application (Fig. 1).

Seed and haulm yield of cowpea was significantly influenced by residual effect of organic sources and fertilizer doses applied to preceding maize studied and reported by Stephen and Christopher [8]. Thus, overall improved growth coupled with increased net photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structure on the other hand, might have improved the seed and haulm yield [9]. Similar findings were also reported by Geetha and Varghese [10] in vegetable cowpea.

3.4 Total Primary Nutrients Uptake by Cowpea

Significantly higher total uptake of N, P and K by cowpea (68.94, 14.67 and 61.39 kg N, P and K ha^{-1}, respectively) was recorded in 100% RDF through water soluble fertilizers at 4 DI (T_5) than all other treatments (Fig. 2). 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 [11] 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. Similarly, Chaudhary et al. [12] observed higher dry matter in chickpea resulted in higher uptake of nutrients in site specific nutrient management approach.

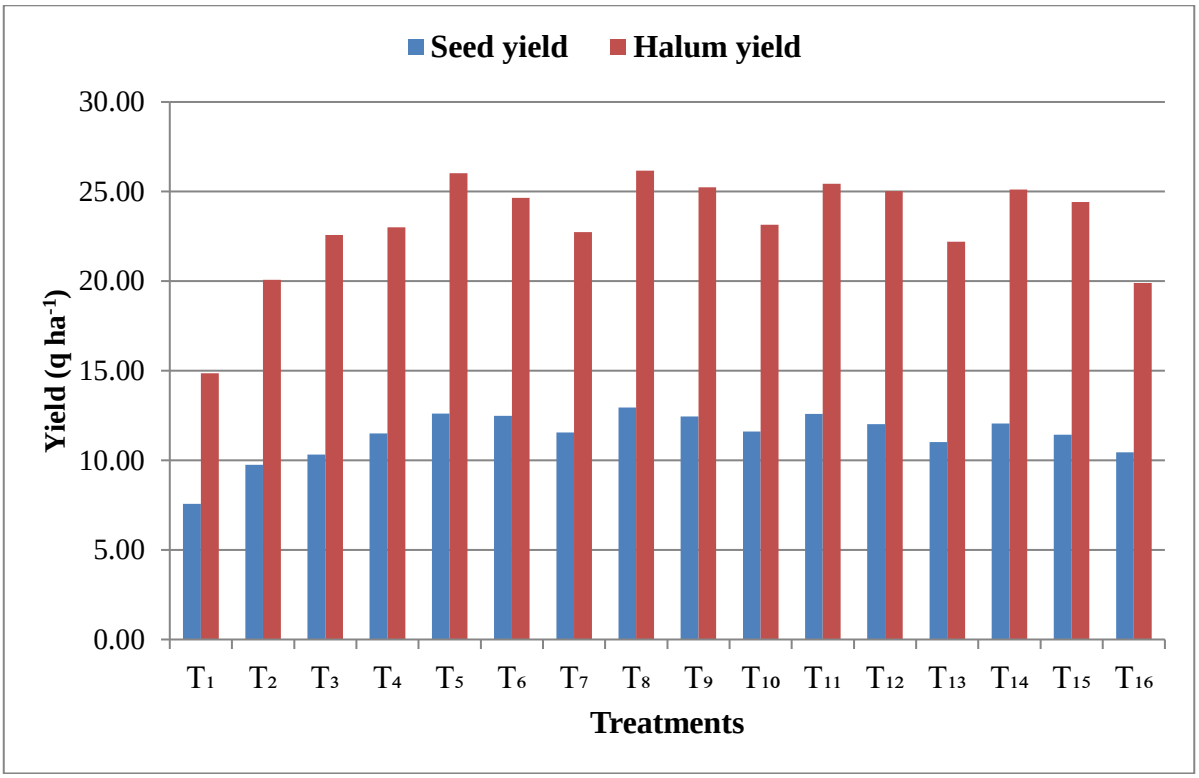

Fig. 1. Residual effect of fertigation of water soluble fertilizers on seed and haulm yield of cowpea under aerobic rice-cowpea cropping sequence

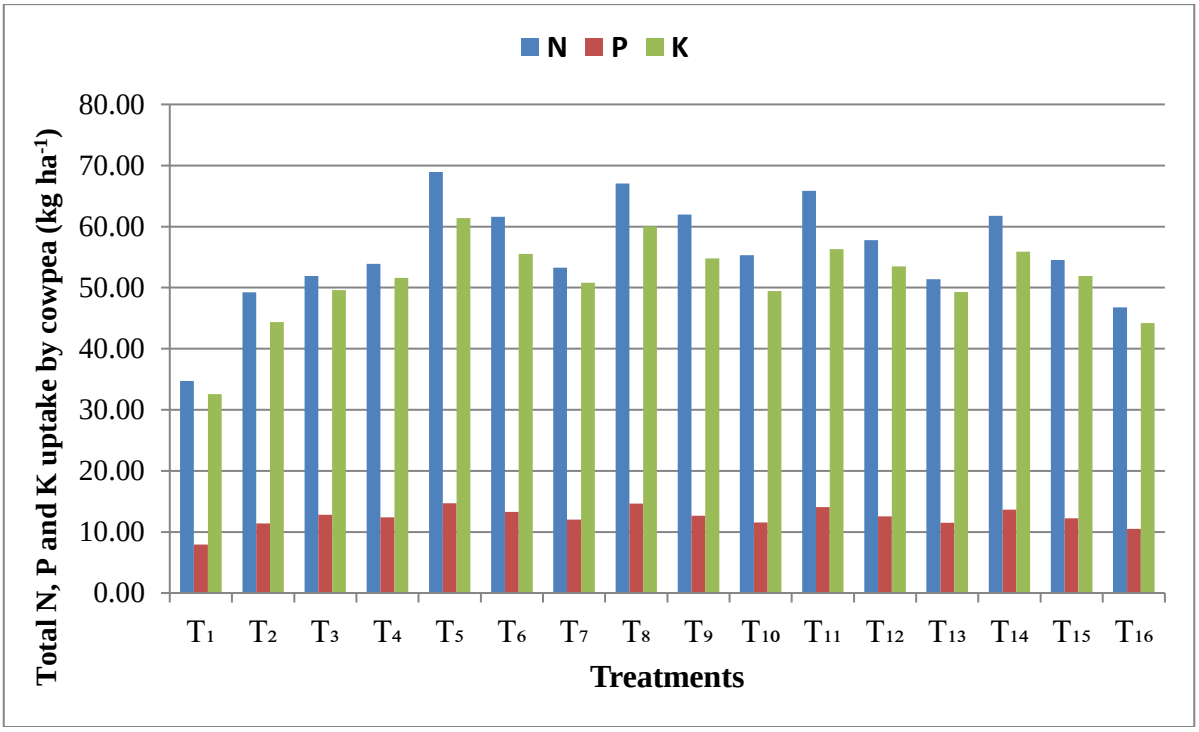

Fig. 2. Residual effect of fertigation of water soluble fertilizer on total primary nutrients uptake by cowpea under aerobic rice-cowpea cropping sequence

Table 2. Residual effect of fertigation of water soluble fertilizers on growth parameters of cowpea under rice-cowpea cropping sequence

Treatments	Plant height (cm)			Number of branches plant			Total dry matter accumulation plant (g)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1-Control	39.67	36.00	37.83	7.83	9.05	8.44	43.33	45.71	44.52
T_2-100% RDF-CF	48.80	50.08	49.44	10.33	10.47	10.40	56.67	57.80	57.23
T_3-100%RDF-CF 4 DI	56.40	51.31	53.86	10.81	10.73	10.77	65.41	65.73	65.57
T_4-100%RDF-CF 8 DI	53.00	55.29	54.15	11.33	10.80	11.07	62.25	65.17	63.71
T_5-100%RDF-WSF 4 DI	56.80	58.59	57.69	11.87	11.20	11.53	69.33	70.41	69.87
T_6-50%RDF-WSF 4 DI	54.40	53.79	54.10	10.93	10.70	10.82	66.89	66.02	66.46
T_7-30%RDF-WSF 4 DI	45.20	44.35	44.78	10.20	9.87	10.03	61.33	61.28	61.31
T_8-100%RDF-WSF 8 DI	60.61	56.32	58.47	11.54	11.87	11.71	70.74	70.47	70.60
T_9-50%RDF-WSF 8 DI	53.53	55.22	54.38	10.53	10.97	10.75	65.31	65.33	65.32
T_{10}-30% RDF-WSF 8 DI	44.84	44.70	44.77	10.33	9.80	10.07	60.82	61.45	61.13
T_{11}-100%STCR dose-WSF 4 DI	55.80	55.53	55.67	11.04	11.07	11.05	68.08	67.33	67.71
T_{12}-50%STCR dose -WSF 4 DI	56.67	50.62	53.64	10.93	10.33	10.63	65.09	64.33	64.71
T_{13}-30%STCR dose -WSF 4 DI	45.93	44.81	45.37	10.00	10.40	10.20	60.87	61.06	60.97
T_{14}-100%STCR dose -WSF 8 DI	56.60	56.00	56.30	11.08	11.10	11.09	67.33	67.01	67.17
T_{15}-50%STCR dose -WSF 8 DI	55.07	52.91	53.99	10.93	10.57	10.75	65.15	65.63	65.39
T_{16}-30%STCR dose -WSF 8 DI	44.53	45.36	44.95	9.88	9.43	9.66	60.98	61.81	61.40
SEm ±	**1.91**	**2.37**	**2.12**	**0.38**	**0.33**	**0.35**	**01.93**	**01.78**	**01.86**
CD at 5%	**5.51**	**6.85**	**5.99**	**1.08**	**0.94**	**0.99**	**05.56**	**05.13**	**05.27**

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

Table 3. Residual effect of fertigation of water soluble fertilizers on yield parameters of cowpea under rice-cowpea cropping sequence

Treatments	Number of pods plant^{-1}			Pod length (cm)			Number of seeds pod^{-1}			Test weight (g)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1-Control	9.89	10.03	9.96	12.51	11.86	12.19	9.05	9.13	9.09	8.20	8.51	8.36
T_2-100% RDF-CF	12.67	11.00	11.83	14.12	14.86	14.49	13.47	11.33	12.40	9.85	9.59	9.72
T_3-100%RDF-CF 4 DI	14.07	13.40	13.73	15.81	15.13	15.47	13.73	13.73	13.73	9.91	10.24	10.07
T_4-100%RDF-CF 8 DI	12.53	12.67	12.60	15.02	14.83	14.93	14.33	14.60	14.47	11.00	11.17	11.08
T_5-100%RDF-WSF 4 DI	16.80	16.00	16.40	16.34	16.33	16.34	16.00	16.17	16.08	11.97	11.73	11.85
T_6-50%RDF-WSF 4 DI	14.17	14.43	14.30	16.00	15.92	15.96	15.08	14.67	14.88	10.51	11.67	11.09
T_7-30%RDF-WSF 4 DI	12.07	11.87	11.97	13.83	13.83	13.83	13.40	12.13	12.77	10.73	10.00	10.37
T_8-100%RDF-WSF 8 DI	17.00	16.17	16.58	16.58	16.75	16.67	16.17	16.03	16.10	11.94	11.92	11.93
T_9-50%RDF-WSF 8 DI	14.00	14.50	14.25	16.37	16.28	16.33	14.60	14.37	14.48	10.61	11.53	11.07
T_{10}-30% RDF-WSF 8 DI	12.73	11.67	12.20	13.63	13.50	13.57	11.73	11.48	11.61	9.78	9.44	9.61
T_{11}-100%STCR dose-WSF 4 DI	16.87	15.40	16.13	16.47	16.78	16.63	15.87	15.40	15.63	11.63	11.69	11.66
T_{12}-50%STCR dose -WSF 4 DI	14.80	13.93	14.37	15.82	15.40	15.61	14.60	14.67	14.63	10.60	11.08	10.84
T_{13}-30%STCR dose -WSF 4 DI	10.67	11.60	11.13	13.10	13.23	13.16	11.73	12.78	12.26	9.87	9.92	9.90
T_{14}-100%STCR dose -WSF 8 DI	15.07	15.87	15.47	16.63	16.67	16.65	16.59	14.55	15.57	11.13	11.83	11.48
T_{15}-50%STCR dose -WSF 8 DI	13.53	14.00	13.77	15.70	16.40	16.05	14.49	14.43	14.46	11.00	10.83	10.92
T_{16}-30%STCR dose -WSF 8 DI	11.73	12.27	12.00	13.57	13.85	13.71	12.50	11.43	11.97	9.97	10.67	10.32
SEm ±	**0.76**	**0.88**	**0.83**	**0.25**	**0.29**	**0.27**	**0.56**	**0.61**	**0.59**	**0.40**	**0.43**	**0.41**
CD at 5%	**2.20**	**2.55**	**2.34**	**0.72**	**0.84**	**0.77**	**1.63**	**1.75**	**1.68**	**1.15**	**1.24**	**1.16**

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

Table 4. Residual effect of fertigation of water soluble fertilizers on total uptake of secondary nutrients uptake by cowpea under aerobic rice-cowpea cropping sequence

Treatments	Calcium uptake (kg ha^{-1})			Magnesium uptake (kg ha^{-1})			Sulphur uptake (kg ha^{-1})		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1-Control	24.14	23.66	23.90	12.53	11.35	11.94	5.76	5.79	5.77
T_2-100% RDF-CF	32.49	33.03	32.76	16.55	15.63	16.09	7.66	7.98	7.82
T_3-100% RDF-CF 4 DI	37.11	37.85	37.48	18.81	17.28	18.05	8.59	9.04	8.81
T_4-100% RDF-CF 8 DI	37.66	40.67	39.16	20.15	18.86	19.50	9.39	10.80	10.09
T_5-100% RDF-WSF 4 DI	47.81	49.27	48.54	25.27	22.61	23.94	11.36	11.91	11.63
T_6-50% RDF-WSF 4 DI	41.62	41.33	41.48	21.06	19.89	20.47	9.42	10.55	9.98
T_7-30% RDF-WSF 4 DI	38.14	37.86	38.00	19.51	18.11	18.81	8.70	9.24	8.97
T_8-100% RDF-WSF 8 DI	50.02	51.40	50.71	26.02	23.40	24.71	11.73	12.45	12.09
T_9-50% RDF-WSF 8 DI	43.12	44.07	43.60	21.31	21.09	21.20	9.64	10.88	10.26
T_{10}-30% RDF-WSF 8 DI	39.30	38.66	38.98	20.20	18.43	19.32	9.00	9.33	9.16
T_{11}-100% STCR dose -WSF 4 DI	46.38	45.17	45.78	25.18	23.35	24.27	10.58	12.34	11.46
T_{12}-50% STCR dose -WSF 4 DI	41.32	42.04	41.68	21.98	20.17	21.08	9.71	10.40	10.06
T_{13}-30% STCR dose -WSF 4 DI	36.48	38.33	37.40	18.65	18.20	18.42	8.44	9.49	8.96
T_{14}-100% STCR dose -WSF 8 DI	44.34	44.02	44.18	22.98	22.27	22.63	10.21	11.86	11.03
T_{15}-50% STCR dose -WSF 8 DI	38.78	39.50	39.14	20.55	19.45	20.00	9.12	9.34	9.23
T_{16}-30% STCR dose -WSF 8 DI	31.83	33.33	32.58	16.47	16.33	16.40	7.43	7.86	7.65
SEm ±	**2.83**	**2.77**	**2.85**	**1.21**	**1.31**	**1.29**	**0.59**	**0.65**	**0.61**
CD at 5%	**8.18**	**8.00**	**8.07**	**3.50**	**3.78**	**3.64**	**1.70**	**1.87**	**1.73**

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

Table 5. Residual effect of fertigation of water soluble fertilizers on total uptake of micronutrients by cowpea under aerobic rice-cowpea cropping sequence

Treatments	Iron uptake (g ha^{-1})			Zinc uptake (g ha^{-1})			Manganese uptake (g ha^{-1})			Copper uptake (g ha^{-1})		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1-Control	385.11	334.24	359.67	50.05	42.24	46.14	109.70	81.74	95.72	22.16	17.54	19.85
T_2-100% RDF-CF	506.67	467.47	487.07	67.49	58.66	63.08	143.58	112.66	128.12	28.99	25.10	27.04
T_3-100% RDF-CF 4 DI	557.75	527.58	542.66	72.81	67.52	70.17	161.13	127.35	144.24	32.13	28.73	30.43
T_4-100% RDF-CF 8 DI	582.27	567.27	574.77	76.22	72.35	74.28	163.20	137.43	150.32	33.42	30.36	31.89
T_5-100% RDF-WSF 4 DI	681.83	624.70	653.27	86.73	83.07	84.90	191.46	153.45	172.46	39.91	32.85	36.38
T_6-50% RDF-WSF 4 DI	640.98	607.09	624.04	84.74	72.91	78.83	181.10	142.14	161.62	37.49	32.39	34.94
T_7-30% RDF-WSF 4 DI	574.21	550.05	562.13	76.41	69.48	72.94	163.46	131.89	147.68	34.06	30.59	32.33
T_8-100% RDF-WSF 8 DI	698.55	661.91	680.23	96.69	85.92	91.30	195.44	156.16	175.80	41.46	35.07	38.27
T_9-50% RDF-WSF 8 DI	671.69	623.62	647.65	88.81	75.79	82.30	188.39	144.12	166.25	39.71	33.59	36.65
T_{10}-30% RDF-WSF 8 DI	599.53	554.34	576.94	78.81	72.33	75.57	169.95	134.28	152.11	35.61	31.16	33.38
T_{11}-100% STCR dose -WSF 4 DI	668.55	656.00	662.27	91.49	84.71	88.10	200.04	163.30	181.67	40.15	35.55	37.85
T_{12}-50% STCR dose -WSF 4 DI	619.28	581.37	600.32	83.58	74.69	79.13	179.34	143.40	161.37	37.36	32.62	34.99
T_{13}-30% STCR dose -WSF 4 DI	545.54	538.01	541.78	72.33	68.63	70.48	160.61	130.57	145.59	32.65	29.41	31.03
T_{14}-100% STCR dose -WSF 8 DI	654.86	621.28	638.07	87.57	82.11	84.84	191.17	158.26	174.72	37.95	34.10	36.03
T_{15}-50% STCR dose -WSF 8 DI	607.32	555.30	581.31	81.44	70.49	75.96	173.54	138.92	156.23	35.92	31.11	33.51
T_{16}-30% STCR dose -WSF 8 DI	512.46	477.07	494.77	65.05	59.40	62.22	146.10	118.98	132.54	29.76	26.39	28.08
SEm ±	**35.16**	**37.73**	**35.94**	**5.32**	**4.60**	**4.97**	**11.15**	**5.30**	**9.27**	**1.86**	**1.56**	**1.71**
CD at 5%	**101.54**	**108.97**	**101.59**	**15.38**	**13.29**	**14.06**	**32.20**	**15.32**	**26.20**	**5.36**	**4.50**	**4.84**

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

Table 6. Correlation coefficients between the growth and yield parameters of cowpea with total nutrient uptake by cowpea

Cowpea	Plant height	No of branches per plant	DMA per plant	No of pods per plant	Pod length	No of seeds per pod	Test weight	Seed yield	Haulm yield
N uptake	0.856**	0.899**	0.911**	0.919**	0.860**	0.919**	0.915**	0.948**	0.952**
P uptake	0.916**	0.963**	0.949**	0.921**	0.886**	0.958**	0.919**	0.892**	0.936**
K uptake	0.871**	0.930**	0.955**	0.887**	0.846**	0.940**	0.930**	0.960**	0.978**

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed). Pearson's correlation coefficients are presented. "*" denotes p < 0.05 and "**" denotes p < 0.01*

3.5 Total Secondary Nutrients Uptake by Cowpea

Among the 16 different treatments tried in the present research study, where 100% RDF through WSF at 8 DI (T_8) was recorded significantly higher total Ca, Mg and S calcium uptake by cowpea (50.71, 24.71 and 12.09 kg Ca, Mg and S ha^{-1}, respectively) than all other treatments (Table 4). This may be due to addition of secondary nutrients through the application of higher doses of WSF (NPK) for previous aerobic rice crop and also supplied from native soil might have resulted in higher availability of secondary nutrients near active root zone which may leads to higher uptake of secondary nutrients due to increase in the biomass yield of succeeding cowpea crop. Similarly, in case of WSF where nutrients are 100% soluble in water resulted in higher availability of nutrients which may resulted in higher uptake of secondary nutrients during crop growth period might have attributed for higher biomass production than conventional fertilizers and the present results are also in line with the findings of Shanmugam and Veeraputhran [13].

3.6 Total Micronutrients Uptake by Cowpea Crop

Significantly higher uptake of total Fe by cowpea crop (680.23 g ha^{-1}) was recorded with 100% RDF through water soluble fertilizers at 8 DI (T_8) than other treatments. 100% RDF through water soluble fertilizers at 8 days (DI) interval (T_8) was recorded significantly higher uptake of total Zn by cowpea (91.30 g ha^{-1}) than other treatments. Significantly higher total uptake of Mn by residual cowpea crop was observed (181.67 g ha^{-1}) in 100% STCR dose through water soluble fertilizers at 4 DI (T_{11}) than other treatments. The treatment with 100% RDF through water soluble fertilizers at 8 DI (T_8) was showed significantly higher total Cu uptake by residual cowpea crop (38.27 g ha^{-1}) than other treatments (Table 5). This may be due to additional amount of nutrients supplied by organics and NPK fertilizers which were applied for previous rice crop may be providing conducive physical environment facilitating better root growth and absorption of nutrients from the native as well as decomposition of crop litter from the previous rice crop which ultimately favoured in the higher production of biomass yield which may attributed for higher uptake of micronutrients by residual cowpea crop. Similarly, the present study findings were in line with results of Shruthi [14] who revealed that increased in the uptake of micronutrients by residual cowpea was observed due to application of FYM to grow rice crop might be attributed to increase the availability of these nutrients by chelating effect of organic ligands by applied organic manures through mineralization process. Similarly, Pandey et al. [15] also reported that organic manures producing favourable changes in soil, which might have resulted in loose and friable soil condition and enabled better root formation. The organic manures were found to reduce nutrient losses and conserve soil nutrients to form organo-mineral complex, maintained supply of nutrients to rice plant.

3.7 Correlation Coefficient between the Growth and Yield Attribute with Nutrient Uptake

Correlation between plant growth and yield parameter of cowpea and their nutrients uptake in cowpea are shown in Table 6. There was a significantly positive correlation between the growth and yield parameters of cowpea with total nutrients (NPK) uptake by cowpea.

Seed yield of cowpea was found to be positively correlated with parameters such as plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$ and pod weight. These parameters were significantly improved by the application of nitrogen fertilizer and hence significant increase in grain yield. The importance of plant height as a function of yield had been reported for other crops [16,17]. It is therefore been suggested that the final plant height may be taken as a simple integral measure of growth response to moisture and nutrient stress [17]. The positive correlation between seed yield and number of pods $plant^{-1}$, phosphorus is essential for photosynthesis, pod development and grain filling in leguminous crops and also responsible for nodulation in cowpea. Thus, higher nodulation resulted in higher nitrogen fixation and eventually the number of pods $plant^{-1}$. This positive response recorded on both seed yield and haulm yield of succeeding crop cowpea could be due to mineralization of nutrients during decomposition of FYM and also acids were released during decomposition might have released the native nutrients from the soil pool and some extent the amount of available nutrients were left in the soil where added through different treatments for the previous aerobic rice crop, from all these pools more nutrients were available for plant uptake.

4. CONCLUSION

It is concluded from the current study fertigation with 100% RDF through water soluble fertilizer at 8 DI improved the growth and yield as compared to other treatments. While higher total uptake of N, P and K was recorded in 100% RDF through water soluble fertilizers at 4 DI (T_5), and application of 100% RDF through WSF at 8 DI (T_8) was recorded notably higher total Ca, Mg and S uptake by cowpea. Similarly higher uptake of total Fe, Zn and Cu was recorded with 100% RDF through water soluble fertilizers at 8 DI (T_8) and Total uptake of Mn was recorded higher by cowpea was observed in 100% STCR dose through water soluble fertilizers at 4 DI (T_{11}). Therefore, application of fertigation with 100% RDF through water soluble fertilizer at 8 DI can be recommended to farmers for achieving maximum yield in cowpea.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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