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Effect of Fertigation of Graded Levels of Water-Soluble Fertilizers through STCR Approach on Soil Properties in Aerobic Rice

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ABSTRACT

A field experiment was carried out at ZARS, UAS, GKVK, Bengaluru to study the effect of fertigation of graded levels of water-soluble fertilizers through STCR approach on soil properties in aerobic rice during *kharif* 2015 and 2016. The present investigation includes 16 different treatment, combinations replicated thrice with RCBD design where hybrid rice (KRH 4) was the test crop grown under aerobic condition. The results indicated that, significantly higher grain and straw yield of rice were recorded in treatment, which received fertigation with 100 per cent STCR dose through water soluble fertilizers (WSF) at eight (8 times) days interval over soil application of 100 per cent conventional fertilizers as per Package of Practices. There was no significant difference in soil pH and EC values between the imposed treatments. However, the organic carbon (OC) content of 0.64 per cent was recorded with 100 per cent STCR dose through WSF at four days interval of fertigation (T_{11}) which was significantly higher than other treatments except T_4,T_5,T_8 and T_{14}, which were statistically on par. Similarly, the treatments which received the water-soluble fertilizers through STCR approach, irrespective of intervals of fertigation have maintained significantly higher NPK status in the soil compared to soil application of conventional fertilizers as per PoP followed by fertigation of conventional and water soluble fertilizers through RDF approach. However, significantly higher exchangeable Ca, Mg and available S content in the soil (4.49, 2.64 cmol (p^+) kg^{-1} and 16.66 mg kg^{-1}, respectively) were recorded in 100 per cent RDF through conventional fertilizer as per PoP (T_2) followed by other conventional fertilizers received treatments (T_3 and T_4) and the treatment with 100 per cent RDF or STCR dose through WSF, irrespective of intervals of fertigation, which were statistically on par. There was no much significant difference between the treatments with respect to micronutrients availability in the soil except control.

Keywords : Fertigation, Water-Soluble fertilizers, Conventional fertilizers, STCR approach, Aerobic rice

RICE (*Oryza sativa* L.) is one of the most important food crops in the world. In Asia, more than two billion people are getting 60-70 per cent of their food energy from rice. The present and future food security of Asia and India depends upon the irrigated rice production system. Moreover rice producing countries are facing water scarcity now than ever before and nutrient management is also one of the major challenge, which threatens the sustainability of irrigated rice ecosystem and improper nutrient management practices causes adverse effect on soil health. Among the various techniques of irrigation methods, drip irrigation is the most efficient method of delivering water to the root zone and applying fertilizers through irrigation water particularly through the drip system is termed as fertigation, it provides the most effective way of supplying nutrients to the plant root and greatly reduced the pollution risk to the environment. Thus, fertigation becomes one of the precision nutrient management strategies for increasing the yield of aerobic rice. Fertigation minimises loss of NK when precisely required quantity of nutrients are supplied directly to the root zone in available forms at the right time (Jata *et al.,* 2013). Similar observations of increased nutrient uptake and lesser leaching of NO_3-N and K to deeper layer of soil by fertigation with WSF has been reported by Yoshida *et al*. (2011). Further, fertigation of water-soluble fertilizer had higher concentration of available plant nutrients in top layer over normal fertilizer (Hebbar *et al*., 2004) compared to soil application of conventional fertilizer where N movement to deeper layer results in lower amount of available N content in soil at shallow depth and unable to supply the required quantity of N to crop (Mahendra *et al.,* 2011). Phosphorus applied through conventional fertilizers converted into insoluble form or fixed at a point of application without any further movement. However, in case of available K through conventional fertilizer where uptake was less may be due to leaching of K along with water to deeper layer which attributed for lesser available K content in soil.

The application of balanced fertilization through Soil Test Crop Response (STCR) equations by considering the contribution of nutrients from soil, fertilizer and manure based on yield target might have resulted in higher uptake with maintaining higher yield than other fertilizer management practices. 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. Based on the above discussion the present study was initiated to compare the effect of different forms and levels of fertilizers application through STCR and Recommended Dose of Fertilizers (RDF) approaches to achieve sustainable yield of aerobic rice and to improve soil properties.

MATERIAL AND METHODS

Experimental Details

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, Bengaluru. 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 per cent RDF-Conventional fertilizers through soil application as per PoP, T_3:100 per cent RDF-Conventional fertilizers through fertigation at 4 days interval (DI), T_4:100 per cent RDF-Conventional fertilizers through fertigation at 8 days interval, T_5:100 per cent RDF-Water soluble fertilizers through fertigation at 4 days interval, T_6:50 per cent RDF-Water soluble fertilizers through fertigation at 4 days interval, T_7:30 per cent RDF-Water soluble fertilizers through fertigation at 4 days interval, T_8:100 per cent RDF-Water soluble fertilizers through fertigation at 8 days interval, T_9:50 per cent RDF-Water soluble fertilizers through fertigation at 8 days interval, T_{10}:30 per cent RDF-Water soluble fertilizers through fertigation at 8 days interval, T_{11}:100 per cent STCR-Water soluble fertilizers through fertigation at 4 days interval, T_{12}:50 per cent STCR-Water soluble fertilizers through fertigation at 4 days interval, T_{13}:30 per cent STCR-Water soluble fertilizers through fertigation at 4 days interval, T_{14}:100 per cent STCR-Water soluble fertilizers through fertigation at 8 days intervals, T_{15}:50 per cent STCR-Water soluble fertilizers through fertigation at 8 days intervals and T_{16}:30 per cent 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 @ 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 except for the absolute control treatment. For treatment T_2, where N was applied in three split doses *viz.*, 50 per cent as basal, the remaining

50 per cent nitrogen was top dressed in two equal splits during active tillering and before panicle initiation stage, 100 per cent 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 @ 30, 50 and 30 per cent (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 per cent 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 80 days after sowing or panicle initiation stage to each plot as per the treatments. Irrigation schedule was common for all the treatments.

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. 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 during both the years and analysis was done as per the standard procedures.

The soil of the experimental field was sandy clay loam in texture and neutral in soil reaction (6.72). The initial fertility status of soil showed low OC (0.48%) content. 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 in available secondary and DTPA extractable micronutrients content (Table 1).

TABLE 1

Initial soil physical and chemical properties of the experimental site

Particulars	Value obtained
Physical properties of soil	
Course sand (%)	33.08
Fine sand (%)	36.13
Silt (%)	7.43
Clay (%)	23.56
Texture	Sandy clay loam
Chemical properties of soil	
pH (1:2.5)	6.72
Electrical conductivity (dS m^{-1})	0.08
OC (%)	0.48
CEC [cmol (p+) kg^{-1}]	8.12
Available N (kg ha^{-1})	212.59
Available P_2O_5 (kg ha^{-1})	21.98
Available K_2O (kg ha^{-1})	210.43
Exch.Ca [cmol (p$^+$) kg^{-1}]	3.96
Exch. Mg [cmol (p$^+$) kg^{-1}]	2.63
Available S (mg kg^{-1})	17.60
DTPA Zn (mg kg^{-1})	1.65
DTPA Fe (mg kg^{-1})	18.28
DTPA Cu (mg kg^{-1})	0.61
DTPA Mn (mg kg^{-1})	23.91

The quantity of fertilizers for STCR treatments (T_{11} to T_{16}) required for a yield of 80 q ha^{-1} were calculated (Table 2) by using STCR targeted yield equation developed at ZARS, V.C. Farm, Mandya (Prakash *et al*., 2007) and is as follows.

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

FP_2O_5 = 1.636 T- 0.256 SP_2O_5 x Olsen.P_2O_5-0.77 x OM

FK_2O = 2.31T- 0.493 SK_2O x Amm.Ace.K_2O-1.14 x 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 2

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

The drip fertigation levels, approaches, forms of fertilizers and intervals of fertigation have profound influence on the grain and straw yield of rice. The results of the present study indicated that the treatment with 100 per cent STCR dose through WSF at 8 days interval (DI) of fertigation recorded significantly higher grain and straw yield (62.98 and 85.26 q ha^{-1}, respectively) of aerobic rice (Table 3) compared to soil application of 100 per cent conventional fertilizers as per PoP (T_2) followed by treatments which received the conventional fertilizers through fertigation (T_3 & T_4) and also control treatment (T_1). This increase in the yield of rice under drip irrigation might be due to efficient utilization of water and higher absorption of nutrients by the crop with maintenance of excellent soil-water-air relationship with higher oxygen concentration in the root zone (Sharma *et al*., 2013). Babu *et al*. (2018) has reported that the increased yield in drip fertigation than soil application which was because of the constant nutrient availability during the entire crop growth period. Further, it may be ascribed to its complete solubility of water soluble fertilizers and enhanced availability of nutrients near the effective root zone than conventional fertilizers. This might have resulted in more uptake of nutrients and intern higher yield in STCR targeted yield approach than soil application of conventional fertilizers. Similar findings were stated by Raina *et al*. (2011); Shruthi & Gowda (2017); Tadesse *et al.* (2013) and Murali & Setty (2001). Pradeep and Parmanand (2018) who reported higher yield under STCR approach which differed significantly with recommended dose of fertilizer and farmer's fertilizer practice. The higher grain and straw

TABLE 3
Effect of fertigation of graded levels of water soluble fertilizers through STCR approach on grain and straw yield of aerobic rice under rice-cowpea cropping sequence

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1 - Control	33.80	39.46
T_2 - 100% RDF-CF	47.71	58.01
T_3 - 100% RDF-CF 4 DI	52.43	61.60
T_4 - 100% RDF-CF 8 DI	49.10	57.48
T_5 - 100% RDF-WSF 4DI	55.78	63.57
T_6 - 50% RDF-WSF 4DI	49.23	57.04
T_7 - 30% RDF-WSF 4 DI	40.78	45.79
T_8 - 100% RDF-WSF 8 DI	58.78	69.17
T_9 - 50% RDF-WSF 8 DI	51.26	59.85
T_{10} - 30% RDF-WSF 8 DI	45.99	51.97
T_{11} - 100% STCR dose -WSF 4 DI	58.98	82.56
T_{12} - 50% STCR dose -WSF 4 DI	49.29	61.77
T_{13} - 30% STCR dose -WSF 4 DI	44.97	55.51
T_{14} - 100% STCR dose -WSF 8 DI	62.98	85.26
T_{15} - 50% STCR dose -WSF 8 DI	51.07	64.63
T_{16} - 30% STCR dose -WSF 8 DI	48.11	59.32
SEm±	2.74	3.30
CD at 5%	7.74	9.33

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

yield of aerobic rice might be due to addition of exact quantity of NPK fertilizers through STCR approach compared to blanket recommendation or RDF reported by Vidyavathi *et al.* (2012). As a whole, the amalgamation of STCR-IPNS approach of fertilizer prescription together with drip fertigation proclaimed the improvement in yield by rising fertilizer use efficiency and timely supply of nutrients than that of adopting the same approach through the conventional method of fertilizer application and surface irrigation even though in similar condition.

Soil Chemical Properties

Soil pH, EC and OC Content

There was no significant difference in soil pH and EC values between the 16 treatments. This might be because of buffering action of soil due to use of balanced way of nutrients supply through both organic and inorganic sources under STCR approach (Table 4). Santhi and Selvakumari (1999) reported that continuous addition of varying quantities of inorganic fertilizers in combination with FYM did not alter the soil pH and EC appreciably. Similarly, Anil *et al.* (2018) also reported that soil pH and EC remained almost unchanged if balanced fertilizers were used along with

TABLE 4
Effect of fertigation of graded levels of water soluble fertilizers through STCR approach on soil on pH, EC and OC content of soil after harvest of aerobic rice under rice-cowpea cropping sequence

Treatments	pH (1:2.5)	EC (dSm^{-1}) (1:2.5)	OC (%)
T_1 - Control	6.63	0.15	0.45
T_2 - 100% RDF-CF	6.62	0.18	0.52
T_3 - 100% RDF-CF 4 DI	6.63	0.17	0.54
T_4 - 100% RDF-CF 8 DI	6.65	0.14	0.59
T_5 - 100% RDF-WSF 4DI	6.66	0.14	0.59
T_6 - 50% RDF-WSF 4DI	6.69	0.15	0.54
T_7 - 30% RDF-WSF 4 DI	6.70	0.15	0.52
T_8 - 100% RDF-WSF 8 DI	6.68	0.15	0.61
T_9 - 50% RDF-WSF 8 DI	6.70	0.14	0.56
T_{10} - 30% RDF-WSF 8 DI	6.69	0.15	0.53
T_{11} - 100% STCR dose -WSF 4 DI	6.66	0.14	0.64
T_{12} - 50% STCR dose -WSF 4 DI	6.76	0.16	0.54
T_{13} - 30% STCR dose -WSF 4 DI	6.67	0.15	0.51
T_{14} - 100% STCR dose -WSF 8 DI	6.66	0.15	0.61
T_{15} - 50% STCR dose -WSF 8 DI	6.77	0.15	0.54
T_{16} - 30% STCR dose -WSF 8 DI	6.71	0.14	0.49
SEm±	1.16	0.02	0.02
CD at 5%	NS	NS	0.06

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

organic manure (FYM).This might be due to stabilizing effects of FYM by long-term application of integrated nutrients. Teixeira *et al.* (2007) reported in their study, the minimal change in the soil pH and EC during drip fertigation using urea, DAP and MOP. Divya *et al.* (2018) indicated that the pH and EC of soil did not differ significantly due to fertigation and its combination treatments. This might be because the applied nutrients have not affected the salt levels in soil significantly. The soil pH remained almost unchanged if fertilizers were used along with organic manure which might be due to stabilizing effects of applied organics reported by Dwivedi *et al.*(2007) and Dindayal (2015).

The organic carbon (OC) content of 0.64 per cent remained significantly higher with 100% STCR dose through water soluble fertilizers (WSF) at 4 DI of fertigation (T_{11}). However, control treatment (T_1) registered significantly lower OC content in the soil (0.45%). Hadole *et al.* (2012) reported that the significantly higher organic carbon was recorded in the treatment with drip fertigation at 150 per cent RDF and it was found to be at par with treatment drip fertigation at 125 per cent RDF. The lowest organic carbon was recorded in the treatment with traditional fertilization at 100 per cent RDF. Teixeira *et al.* (2007) revealed that the effect of fertigation on soil chemical properties is more diffused because of the spread of fertilizers uniformly than the conventional soil fertilization. With minimal disturbance of the soil and with the supply of irrigation water through drip, soil never attained the anaerobic condition that controls the growth and function of soil microorganisms. This might have augmented in building up the soil organic carbon. Anil *et al.* (2018) revealed that the lowest organic carbon content was in control where no fertilizer was practiced. Babbu *et al.* (2015) confirmed that balanced and integrated use of organic and inorganic fertilizers may enhance the accumulation of soil organic matter and improves soil physical properties. Bandole and More (2000) also reported that there was increase in the organic carbon content in the soil of organics treated plots compared to initial value.

Available Major Nutrients Content in Soil

The present research revealed that, fertigation with 100 per cent STCR dose through WSF at 4 DI treatment recorded significantly higher available N, P_2O_5 and K_2O (178.77, 116.29 and 162.30 kg ha^{-1}, respectively) contents in the soil after the harvest of aerobic rice as compared to the soil application of 100 per cent conventional fertilizer through package of practice followed by fertigation of WSF and conventional fertilizers through RDF and control (Table 5). This might be due to application of higher dose of fertilizers as per the STCR equation could supply the balanced quantity of nutrients to get specific targeted yield of 80 q ha^{-1} in aerobic rice compared to other methods. Hence, there was higher residual available nitrogen, phosphorus and potassium content in soil after the harvest of aerobic rice crop. Manish *et al.* (2017) indicated that the buildup and maintenance of post-harvest soil fertility despite higher removal of nutrients in STCR-IPNS as compared to NPK alone was due to prevention of losses of nutrients under IPNS, even after meeting the crop needs. Similarly, Prabhakar *et al.* (2017) recorded the higher available N (168.8 kg ha^{-1}), P_2O_5 (68.3 kg ha^{-1}) and K_2O (439.6 kg ha^{-1}) in the STCR integrated approach than that of soil test based and RDF which indicated the maintenance of soil fertility under STCR approach due to higher dose of fertilizer application along with vemicompost. Similarly, Choudhary *et al.* (2019) revealed that integrated use of NPK fertilizers with FYM based on STCR approach not only gave higher rice yield but also improved and sustained the soil fertility. The maximum availability of macronutrients to plants by the application of water soluble fertilizers was reported by Kadam *et al.* (2009). Similar results were reported by Shyamaa *et al.* (2009) and Chandrakanth *et al.* (2017).

Secondary Nutrients Content in Soil

Significantly higher exchangeable Ca, Mg and available S content in the soil (4.49, 2.64 cmol (p$^+$) kg^{-1} and 16.66 mg kg^{-1}, respectively) were recorded in 100 per cent RDF through conventional fertilizer as per PoP (T_2) followed by other conventional fertilizers received

TABLE 5

Effect of fertigation of graded levels of water soluble fertilizers through STCR approach on available N, P and K content in soil after harvest of aerobic rice under rice-cowpea cropping sequence

Treatments	Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})
T_1 - Control	109.49	17.48	113.60
T_2 - 100 % RDF - CF	137.15	60.63	133.52
T_3 - 100 % RDF - CF 4 DI	159.02	71.61	147.06
T_4 - 100 % RDF - CF 8 DI	148.83	70.58	140.37
T_5 - 100 % RDF - WSF 4DI	158.44	69.34	153.64
T_6 - 50 % RDF - WSF 4DI	124.83	35.71	134.11
T_7 - 30 % RDF - WSF 4 DI	123.31	27.98	124.50
T_8 - 100 % RDF - WSF 8 DI	163.16	67.36	149.23
T_9 - 50 % RDF - WSF 8 DI	129.57	32.60	129.17
T_{10} - 30 % RDF - WSF 8 DI	121.34	25.39	122.67
T_{11} - 100 % STCR dose - WSF 4 DI	178.77	116.29	162.30
T_{12} - 50 % STCR dose - WSF 4 DI	137.18	72.92	134.44
T_{13} - 30 % STCR dose - WSF 4 DI	126.25	46.88	129.14
T_{14} - 100 % STCR dose - WSF 8 DI	172.79	113.52	158.34
T_{15} - 50 % STCR dose - WSF 8 DI	133.58	65.45	130.78
T_{16} - 30 % STCR dose - WSF 8 DI	121.74	43.35	122.45
SEm±	3.61	3.13	3.24
CD at 5 %	10.20	8.84	9.15

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

treatments and 100 per cent RDF or STCR dose through WSF, irrespective of intervals of fertigation, which were statistically on par. Whereas, significantly lower exchangeable Ca, Mg and available S content (2.72, 1.86 cmol (p^+) kg^{-1} and 10.31 mg kg^{-1}, respectively) were observed in the control (T_1) treatment (Table 6).

The increased Ca content in conventional fertilizers applied plots might be due to addition of some amount of secondary nutrients from the straight fertilizes particularly SSP which contains 18 per cent of Ca. The lower exchangeable Ca status of soil was found in soluble fertilizers applied plots which might be due to higher solubility and uptake of P with corresponding higher uptake of Ca to produce higher biomass production than conventional fertilizer received treatments. Similar result was reported by Bhavya (2021) in aerobic rice. The release of calcium during mineralization process and subsequent retention of calcium by FYM also increased exchangeable Ca content of soil in maize crop (Santhosh, 2013) and (Apoorva *et al.*, 2010) in finger millet crop.

The treatment which received the conventional fertilizers as per the PoP has maintained the higher Mg content in soil that may be due to application of FYM which released more Mg during mineralization process attributing for higher Mg availability in soil and also due to lesser biomass produced in those treatments resulted in lesser uptake of nutrients. This might have also resulted in higher Mg content in soil with conventional fertilizers received treatments. In case of soluble fertilizers applied plots, where efficient

TABLE 6

Effect of fertigation of graded levels of water soluble fertilizers through STCR approach on secondary nutrients contents in soil after harvest of aerobic rice under rice-cowpea cropping sequence

Treatments	Exch.Ca [cmol (p+) kg^{-1}]	Exch. Mg [cmol (p+) kg^{-1}]	Avail. S (mg kg^{-1})
T_1 - Control	2.72	1.86	10.31
T_2 - 100 % RDF - CF	4.49	2.64	16.66
T_3 - 100 % RDF - CF 4 DI	4.36	2.52	16.20
T_4 - 100 % RDF - CF 8 DI	4.46	2.62	16.21
T_5 - 100 % RDF - WSF 4DI	4.19	2.41	16.43
T_6 - 50 % RDF - WSF 4DI	3.87	2.10	14.70
T_7 - 30 % RDF - WSF 4 DI	3.62	2.05	14.03
T_8 - 100 % RDF - WSF 8 DI	4.11	2.44	16.51
T_9 - 50 % RDF - WSF 8 DI	3.69	2.19	13.41
T_{10} - 30 % RDF - WSF 8 DI	3.52	2.17	12.59
T_{11} - 100 % STCR dose - WSF 4 DI	3.93	2.36	16.28
T_{12} - 50 % STCR dose - WSF 4 DI	3.62	2.07	14.56
T_{13} - 30 % STCR dose - WSF 4 DI	3.55	1.99	12.73
T_{14} - 100 % STCR dose - WSF 8 DI	3.87	2.27	16.17
T_{15} - 50 % STCR dose - WSF 8 DI	3.64	2.15	13.86
T_{16} - 30 % STCR dose - WSF 8 DI	3.57	2.01	12.06
SEm± 0.11	0.11	0.08	0.58
CD at 5 %	0.30	0.23	1.65

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

utilization of available Mg from native soil and FYM to produce more biomass yield which might have lead to lesser Mg content in soil. In soybean crop, the higher magnesium content in soil through integrated approach was due to addition of organic manure, which resulted in release of magnesium during mineralization process (Shashi, 2003).

The conventional fertilizers received treatments registered higher sulphur status in soil than the water soluble fertilizer applied treatments and control. This may be due to addition of SSP as a source of P which contains 11 per cent S, mineralization of S from FYM and also due to oxidation of elemental S from the native soil by microorganisms. The present investigation results were in line with the findings of Chandrakanth (2015) in maize crop who reported that addition of FYM along with SSP have enhanced the available sulphur status in soil. Similar results were also observed by Santhosh (2013) who revealed that FYM either alone or in combination with inorganic fertilizers recorded significantly higher available sulphur content in post-harvest soils of maize crop when compared to water soluble fertilizers received treatments alone.

Micronutrients Content in Soil

There was no much significant difference between the treatments with respect to micronutrients availability in soil except control treatment. Fertigation with 100 per cent RDF or STCR dose received through WSF, irrespective of intervals of fertigation showed numerically higher DTPA extractable micronutrient in

TABLE 7

Effect of fertigation of graded levels of water soluble fertilizers through STCR approach on DTPA extractable micro nutrients content in soil after harvest of rice under aerobic rice-cowpea cropping sequence

Treatments	DTPA extractable Fe (mg kg-1)	Zn	Mn	Cu
T_1 - Control	16.03	1.23	18.73	0.42
T_2 - 100 % RDF - CF	17.39	1.51	21.62	0.57
T_3 - 100 % RDF - CF 4 DI	18.00	1.50	21.56	0.51
T_4 - 100 % RDF - CF 8 DI	15.82	1.49	22.93	0.51
T_5 - 100 % RDF - WSF 4DI	19.70	1.62	24.57	0.55
T_6 - 50 % RDF - WSF 4DI	17.84	1.51	22.16	0.56
T_7 - 30 % RDF - WSF 4 DI	14.53	1.44	20.70	0.58
T_8 - 100 % RDF - WSF 8 DI	22.11	1.67	22.76	0.60
T_9 - 50 % RDF - WSF 8 DI	18.40	1.40	21.63	0.59
T_{10} - 30 % RDF - WSF 8 DI	17.54	1.40	19.88	0.60
T_{11} - 100 % STCR dose - WSF 4 DI	19.64	1.63	24.41	0.62
T_{12} - 50 % STCR dose - WSF 4 DI	18.43	1.50	22.59	0.58
T_{13} - 30 % STCR dose - WSF 4 DI	17.55	1.49	21.65	0.58
T_{14} - 100 % STCR dose - WSF 8 DI	19.59	1.66	21.71	0.56
T_{15} - 50 % STCR dose - WSF 8 DI	18.63	1.42	21.26	0.56
T_{16} - 30 % STCR dose - WSF 8 DI	17.95	1.36	21.23	0.57
SEm±	0.96	0.07	1.34	0.05
CD at 5%	2.71	0.19	3.80	0.14

soil after harvest of aerobic rice (Table7) compared to soil application of 100 per cent conventional fertilizers as per PoP followed by fertigation with 100 per cent conventional fertilizers received treatments.

The DTPA extractable micronutrients status in the soil increased in the fertigation with NPK-WSF through STCR approach followed by fertigation with WSF and conventional fertilizers through RDF approach compared to control. This may be attributed to an additional source of micronutrients upon mineralization of FYM and dissolution of micronutrients from minerals with the help of acids released during different biochemical reactions taking place in soil. Also soil itself contains higher amount of DTPA extractable micronutrients before conducting the experiment. All these factors helped in increasing the availability of micronutrients in the soil after the harvest of aerobic rice. The present study results showed that the treatments which received the fertigation through WSF have registered higher availability of micronutrients in the soil than conventional fertilizer treatments and these findings are corroborated with the results of Koireng *et al*. (2018) who concluded that increase in the available micronutrients status in soil might be due to the addition of farm yard manure, neem cake and water soluble fertilizers as soil application and fertigation.

Pandey *et al*. (2001) who concluded that the organic manures were found to reduce nutrient losses and conserve soil nutrients to form organo-mineral complex, maintained the supply of nutrients and resulted an increase in the availability of micronutrients in soil. Marimuthu *et al*. (2014) concluded that crop productivity and soil fertility status can be sustained with integrated plant nutrient management practices. Similarly, the slow-release organic manures increased the micro nutrient content in soil and thus had great advantage not only on increasing the productivity of the crop but also improving the available nutrients contents in soil necessary for sustaining crop productivity (Zhang *et al*., 2020). The integrated use of fertilizer with FYM increased the nutrient availability. This might be due to the enhanced microbial activity, conversion of unavailable nutrients including micronutrients into available forms and also due to improved physical, chemical and biological properties of soil (Katkar *et al*., 2011).

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