International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 1239-1244

Received: 22-09-2018
Accepted: 23-10-2018

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Long term effect of integrated nutrient management on macro nutrient uptake under rice-rice sequence

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Abstract
A field experiment entitled "Carbon sequestration and soil health under long term soil fertility management in rice-rice cropping system" was carried out under field conditions during both *kharif* and *rabi* seasons of 2016-2017 and 2017-2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. The results reported that the data regarding influence of long-term use of inorganics, organics and their combination on nutrient uptake at different growth stages in *kharif* and *rabi* during both the years of the study indicated that there was significantly increase with application of 100% RDF in combination with $ZnSO_4$ and FYM @ 5t ha^{-1}. However, it was on par with that of application of 100% RDF along with $ZnSO_4$ @ 40 kg ha^{-1} and significantly superior over other treatments. The application of 50% NPK + 50% N through FYM was on par with 100% RDF.

Keywords: Organic manures, inorganics, nitrogen uptake, potassium

Introduction
Rice (*Oryza sativa* L.) is the principal food crop of the world, contributes to about 60% of the world's food. Rice is the major cereal crop feeding two- third of the global population. Rice occupies one-third of the world's crop land planted to cereals and provides 30-60% of the calories consumed by nearly three billion people (Gurra *et al*., 1998) [4]. Rice production is an important part of Asia's economy.

Continuous use of high level of chemical fertilizers had lead to soil degradation problems, which also proved detrimental to soil health. Long-term fertilizer experiments conducted all over India showed, on an average, that rice removed 20.7 kg N, 5.17 kg P and 35.5 kg K during wet season for every ton of grain yield (Yoshida, 1981) [12]. It is therefore, necessary to apply fertilizer elements particularly N, P and K either through organic or through inorganic sources in optimal quantity to improve and sustain the productivity.

Materials and Methods
A long-term field experiment was initiated in *kharif*, 1989 with rice-rice cropping system at APRRI & RARS, Maruteru, West Godavari. The experiment was carried out under field conditions during *kharif* and *rabi* seasons of 2016-2017 and 2017- 2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. The treatments consisted of control, 100 per cent recommended dose of NPK, 100 per cent recommended dose of NK, 100 per cent recommended dose of PK, 100 per cent recommended dose of NP, 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha, 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha + FYM @ 5 t ha^{-1}, 50 per cent recommended dose of NPK, 50% NPK + 50% N through green manures, 50% NPK + 50% N through FYM, 50% NPK + 25% N through green manures + 25% N through FYM and FYM only @ 10 t/ha. There were twelve treatments laidout in RBD with three replications for both *kharif* and *rabi* seasons in two years of study. Nitrogen was applied through urea in three equal splits (1/3rd basal+1/3rd at tillering+1/3rd at panicle initiation stage). Phosphorus was applied through DAP was used duly taking its N content into account and potassium as muriate of potash (60% K_2O) and zinc as zinc sulphate ($ZnSO_4.7H_2O$).

The entire dose of phosphorus, potassium and zinc were applied as basal. Recommended dose of fertilizer for *kharif* season was 90: 60: 60 N: P_2O_5: K_2O kg ha^{-1} and for *Rabi* season it was 180: 90: 60 N: P_2O_5: K_2O kg ha^{-1}. Well decomposed farmyard manure (FYM) manure and *Calotropis* (green leaf manure) were applied two weeks before transplanting. The experiment on rice – rice sequence as detailed above was repeated on a same site during *kharif* 2016-17 and *Rabi* 2017-18, respectively. Popular cultivars of *kharif* rice and *Rabi* rice, MTU-1061, MTU-1010 respectively, were used for the study. Data was collected on on active carbon pools (MBC, WSC and $KMnO_4$-C) of both *kharif* and *Rabi* rice. The uptake of nutrients at harvest was worked out by using the following formulae. Macronutrients uptake was expressed as kg ha^{-1} and micronutrient uptake was expressed in gha^{-1}.

Results and Discussion

Nitrogen uptake

The data indicated significant differences among the treatments on N uptake at tillering, panicle initiation and grain and straw at harvest stages and had shown an increasing trend with growth.

Irrespective of growth stage of rice and year of the study, the treatments those received organics along with the RDF (T_7) (100% RDF + $ZnSO_4$ + FYM@ 5t ha^{-1}) significantly increased the N uptake over the treatments. The highest N uptake was associated with treatments of NPK applied through organics + 100% NPK. This might be due to added fertilizers and FYM those provided a better availability of N in soil to rice crop. Poor availability and higher loss of nutrients under RDF alone resulted lower uptake. These results were in accordance with the findings of Singh *et al.* (2006b) [10].

The maximum nitrogen uptake (56.39, 99.42, 71.57, 99.84 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18, respectively at tillering stage was registered with application of 100% RDF+ $ZnSO_4$+FYM @ 5 t ha^{-1} (T_7) and It was significantly superior over all other treatments and the lowest (15.61, 17.82, 16.27, 21.52 kg ha^{-1}) nitrogen uptake was observed in control (T_1).

At panicle initiation stage, among the treatments, the application of recommended dose of fertilizer (100% RDF) along with $ZnSO_4$ + FYM @ 5 t ha^{-1} (T_7), was significantly superior over other treatments at both the *kharif* and *rabi* seasons during both the years of study and the lowest nitrogen uptake was observed in control (T_1). This effect might be due to the application of slow nutrient releasing organic manures during mineralization process, restricting the losses of nutrients either through leaching or volatilization resulted in higher nutrient uptake. The results were in agreement with the findings of Gudadhe *et al.* (2011) [3]. Soil physico-chemical properties also might had created suitable environment for the availability and thereby uptake of the nutrients were enhanced by organic manure application.

The highest nitrogen uptake in grain, was observed in T_7 (100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1}) with (80.14, 109.74, 86.92, 110.30 kg ha^{-1} which was significantly superior over other treatments but however it was on par with T_6 in both the years of the study in *kharif* and *rabi*. As anticipated, untreated control (T_1) registered the lowest nitrogen uptake with 24.69, 33.16, 24.85, 33.16 kg ha^{-1} in *kharif*, *Rabi* 2016-17 and *kharif*, *rabi* 2017-18, respectively in grain. The lowest N uptake in control plot by the crop was due to the lower yield obtained in these plots.

The favourable effect of organics on N uptake could be attributed to the release of N during decomposition of organic materials and their uptake by crop. Similar results were obtained by Balasubramanian *et al*., (2002) [1].

Among the inorganic treatments (T_2, T_3, T_4, T_5 T_6 and T_8), the treatment T_6 was significantly superior over other treatments but however it was on par with treatment T_2 in *kharif* season. In *Rabi* season the treatment T_6 was significantly superior over T_3, T_4 and T_8 and however it was on par with T_2 and T_5. Similar results were observed in both the years of study in all growth stages of crop.

All the inorganic treatments of NPK were significantly superior over control. This might be due to higher availability of plant nutrients with fertilization, which resulted in enhanced nutrient uptake in plant tissues and more biomass production at higher total fertilizer application (Islam and Munda, 2012) [5]. The treatment T_6 was on par with treatment T_2 in first year study. Whereas in second year the treatment T_6 (100% RDF + $ZnSO_4$) was significantly superior over treatment T_2 (100% RDF).

The increase in N uptake could be ascribed to reduced N losses *via* denitrification or leaching, which might have improved the synchrony between plant N demand and supply from the soil. The immobilization and mineralization of N in the soil could be regulated by the addition of inorganic fertilizers along with organic matter to improve the N uptake by rice. Increased N uptake might be due to easy transformation of urea into available N with addition of zinc (Kumar *et al*., 1999) [6].

The lowest value of N uptake in control and imbalanced fertilizer treatments whereas combined treatments and balanced dose of fertilizer treatments show highest values.

Phosphorus uptake

The phosphorus uptake was significantly influenced by different treatments. The highest phosphorus uptake was recorded with application of 100% RDF+$ZnSO_4$ + FYM @ 5 t ha^{-1} (T_7) and lowest P uptake was observed in control (T_1) at all the stages of crop. The phosphorus uptake was increased at harvest stage which could be due to increased biomass production with growth.

The highest p uptake by rice at tillering stage was recorded in the treatment T_7 (10.31, 20.83, 13.76, 21.26 kg ha^{-1} in *kharif*, *Rabi* 2016-17 and 2017-18, respectively), it was significantly superior over all other treatments and lowest P uptake (3.79, 4.39, 2.75, 3.39 kg ha^{-1}) was observed in control (T_1).

At panicle initiation stage, the highest P uptake was observed in treatment T_7 (100% NPK+ $ZnSO_4$+ FYM) it was significantly superior over all other treatments in *kharif* season, whereas in *rabi* the treatment T_7 was significantly superior over other treatments but however it was on par with T_6. Lowest P uptake (6.69, 7.96, 6.71, 7.85 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 was observed in control (T_1).

The highest p uptake by rice grain was recorded in the treatment T_7 (17.93, 28.27, 19.64, 27.74 kg ha^{-1}) it was significantly superior over other treatments but however it was on par with treatment T_6 (16.69, 24.40, 19.39, 24.71 kg ha^{-1}). The lowest P uptake was observed in control. Similar results were obtained during both the years of study in *kharif* and *Rabi*.

At harvest stage in rice straw the maximum phosphorus uptake (8.74, 13.44, 11.23, 12.79 kg ha^{-1}) was recorded in the treatment T_7 (RDF + $ZnSO_4$+FYM @ 5 t ha^{-1}) and it was significantly superior over other treatments but however it

was on par with treatment T_6 (7.59, 11.85, 9.98, 10.99 kg ha^{-1}). The lowest phosphorus uptake (2.56, 4.47, 2.19, 3.72 kg ha^{-1}) was recorded in the treatment T_1 (control). Similar results were obtained in *kharif* and *Rabi* during both the years of study.

Among the combined organic and inorganic treatments (T_7, T_9, T_{10} and T_{11}), the treatment T_7 was recorded highest phosphorus uptake and it was significantly superior over T_9, T_{10} and T_{11}. However, the treatment T_9, T_{10} and T_{11} were on par with each other in *Rabi* season. In *kharif* season the treatments T_9 and T_{10} were on par with each other and significantly superior over T_{11} in 2016-17 and 2017-18. Similar results were obtained in all the crop growth stages.

Among the inorganic treatments (T_2, T_3, T_4, T_5 T_6 and T_8), the highest P uptake was observed in treatment T_6 and it was significantly superior over other treatments but however it was on par with treatment T_2. Similar results were obtained in all the crop growth stages during both the years of study in *kharif* and *Rabi*.

The increased uptake of P might be due to higher rates of NPK fertilizers applied, increased root and shoot growth, more availability of nutrients from the added fertilizers and the solubility action of organic acids produced during the decomposition of organic materials thus, resulting in more release of both native and applied P (Bellaki *et al.*, 1998) [2]; Ravanakar *et al.* (1999) [8].

Available P in soil significantly enhanced due to application of organic manures, as indicated in earlier chapter. The increased availability of P resulted in more uptake of P by the plant. The pH of the soil also indicated a positive change i.e. a shift towards neutrality. This positive change enhanced the solubility of different nutrients especially phosphorus in the soil. The form of orthophosphate ion might have converted from PO_4^{3-} to HPO_4^{2-} or even $H_2PO_4^-$ for short periods, which resulted in increased uptake of P in the plants (Tilahun *et al.*, 2013) [11].

Potassium uptake

The data indicated that potassium uptake was significantly influenced by different nutrient treatments at tillering, panicle initiation, grain and straw at harvesting stage. Highest potassium uptake was observed in T_7 with application of 100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1} and lowest was recorded in control. The potassium uptake was higher at harvest stage than tillering and panicle initiation stage.

At tillering stage the maximum potassium uptake (65.72, 114.48, 82.92, 117.71 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18, respectively) was recorded in the treatment T_7 (RDF + $ZnSO_4$ + FYM+ @ 5 t ha^{-1}), it was significantly superior over all other treatments in *kharif* season, where as in *rabi* the treatment T_7 was significantly superior over remaining treatments however it was on par with T_6. The lowest potassium uptake (16.92, 25.49, 20.64, 26.16 kg ha^{-1} in *kharif*, *Rabi* 2016-17 and *kharif*, *rabi* 2017-18, respectively) was recorded in the treatment T_1 (control).

K uptake was ranged from 56.31 to 177.29 in *kharif*,16; 61.83 to 216.25 in *rabi*,17; 54.03 to 183.09 in *kharif*,17; 63.66 to 205.03 kg ha^{-1} in *rabi*,18 at panicle initiation stage. The highest K uptake by rice was recorded by the treatment T_7 it was significantly superior over remaining treatments but however it was on par with treatment T_6 (100% RDF + $ZnSO_4$) in *kharif* season. Whereas in *Rabi*, the treatment T_7 was significantly superior over remaining all other treatments. Lowest K uptake was observed in control (T_1), which was significantly inferior over all other treatments.

The highest potassium uptake in grain, was observed in T_7 (100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1}) with (44.27, 51.00, 42.49, 52.34 kg ha^{-1}) it was significantly superior over remaining treatments but however it was on par with treatment T_6 in *kharif, rabi* during both the years of study. As anticipated, untreated control (T_1) plot registered the lowest potassium uptake (13.91, 19.37, 13.91, 19.21 kg ha^{-1} in *kharif, rabi* 2016-17 and *kharif, rabi* 2017-18, respectively). The lowest K uptake in control plot by the crops is due to the lower yield obtained in these plots.

The K uptake by straw was ranged from 42.32 to 144.23; 57.92 to 186.79; 42.41 to 148.92; 57.66 to 186.65 kg ha^{-1} during *kharif, rabi* during both the years of study. The highest K uptake was observed in 100% RDF + FYM + $ZnSO_4$ (T_7) it was significantly superior over other treatments but however it was on par with treatment T_2 and T_6 and the lowest uptake was observed in control it was statistically inferior to all the treatments under study.

Among the inorganic treatments (T_2, T_3, T_4, T_5 T_6 and T_8), the highest potassium uptake was observed in treatment T_6 and it was significantly superior over other treatments but however it was on par with treatment T_2. Similar results were obtained in all the crop growth stages during both the years of study in *kharif* and *Rabi*.

The improvement in the total uptake of potassium in combined treatments was ascribed to the enhanced soil quality resulting in better availability of K. Thus, the data clearly indicated that for efficient utilization of potash, it is essential to apply FYM. Similar results were also reported by Rasool *et al.* (2008) [7].

The data indicated that the lowest value of uptake in control and imbalanced fertilizer treatments whereas combined treatments and balanced dose of fertilizer treatments showed highest values of potassium uptake.

Additive effect of higher doses of nitrogen and phosphorus and priming effect of starter doses of potassium, caused the release of potassium from non - labile pool to labile pool which resulted in increased uptake from the native soil sources by the potato crop (Reddy, 1972) [9]. Similarly, the combined application of FYM with fertilizers has been reported to enhance K uptake which in turn confirming the present findings.

The results of the present study revealed that the highest potassium uptake was observed in combined organic and inorganic treated plot this might be due to to release of K from organic manures during decomposition and solubilisation and release of native and fixed forms of potassium, charging the soil solution with K^+ ions. The results were in agreement with the findings of Hangarge *et al.* (2002). Production of hydrogen ions during decomposition of organic materials would have helped the release of K from exchange sites or from the fixed pool. The addition of FYM attributed to solubilization effect of plant nutrients leading to increased uptake of K.

Table 1: Effect of long-term use of inorganic fertilizers, organic manures and their combination on nitrogen uptake (kg ha^{-1}) by rice

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	15.61	33.21	24.69	18.95	17.82	37.17	33.16	26.59
T_2 100% RDF	45.42	97.38	69.15	60.71	76.15	118.99	85.32	74.21
T_3 100% NK	39.24	90.87	65.34	54.62	69.74	105.92	86.75	57.62
T_4 100% PK	24.61	58.45	44.13	34.09	39.59	71.25	53.19	42.91
T_5 100% NP	37.58	85.41	63.89	47.12	66.92	97.04	73.99	71.99
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	48.16	107.36	74.89	64.85	88.74	122.00	98.96	80.14
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	56.39	119.72	80.14	73.19	99.42	142.62	109.74	93.49
T_8 50% NPK	25.36	62.73	52.97	37.98	48.62	75.70	59.95	52.19
T_9 50% NPK + 50% N through Green Manures	43.19	94.35	66.41	54.16	65.19	114.68	82.73	72.84
T_{10} 50% NPK + 50% N through FYM	47.14	100.89	69.89	61.07	78.64	120.31	87.24	75.78
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	34.89	79.32	62.18	51.16	63.53	91.94	79.24	66.72
T_{12} FYM only @ 10 t/ha	34.32	74.02	55.26	44.09	40.61	86.35	56.72	48.94
SEm ±	2.557	5.126	3.413	2.428	4.552	6.538	4.378	4.136
CD @ 0.05	7.53	15.19	10.01	7.12	13.35	19.56	12.84	12.13
CV (%)	11.74	10.25	8.14	7.89	10.12	8.06	8.67	10.86

Table 2: Effect of long-term use of inorganic fertilizers, organic manures and their combination on nitrogen uptake (kg ha^{-1}) by rice

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	16.27	31.95	24.85	18.49	21.52	37.49	33.16	26.61
T_2 100% RDF	49.31	98.78	72.62	63.86	78.55	119.40	86.49	77.93
T_3 100% NK	43.59	93.41	61.05	57.09	71.49	107.41	86.58	55.46
T_4 100% PK	25.13	60.35	44.13	36.62	41.43	67.63	53.94	42.15
T_5 100% NP	40.19	87.22	60.32	47.18	68.21	86.76	76.43	71.82
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	60.85	109.35	78.65	74.87	93.12	119.71	100.25	81.75
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	71.57	125.59	86.92	86.13	99.84	138.94	110.30	92.83
T_8 50% NPK	28.39	62.83	47.12	40.51	49.91	74.25	59.06	52.45
T_9 50% NPK + 50% N through Green Manures	50.09	97.89	66.25	60.72	65.73	116.82	86.35	75.22
T_{10} 50% NPK + 50% N through FYM	56.71	101.29	74.89	64.53	80.63	122.05	90.28	78.44
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	40.18	80.39	62.12	55.09	64.24	91.43	81.05	67.80
T_{12} FYM only @ 10 t/ha	36.14	76.72	52.72	48.19	41.75	90.15	59.89	49.06
SEm ±	3.451	5.68	3.113	3.239	4.436	6.448	3.822	3.273
CD @ 0.05	10.12	16.32	9.13	9.50	13.01	18.91	11.21	9.61
CV (%)	7.94	9.51	10.96	8.95	9.17	7.49	7.92	8.27

Table 3: Effect of long-term use inorganic fertilizers, organic manures and their combination on phosphorus uptake (kg ha^{-1}) by rice

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	3.79	6.69	7.35	2.56	4.39	7.96	10.26	4.47
T_2 100% RDF	7.99	17.46	15.96	7.48	14.43	22.53	21.50	10.50
T_3 100% NK	5.43	14.79	13.93	7.41	12.49	18.52	19.42	11.63
T_4 100% PK	5.40	14.15	11.58	4.60	8.19	17.86	14.86	7.46
T_5 100% NP	5.38	14.58	14.66	6.89	10.63	17.68	18.97	10.14
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	8.53	18.35	16.69	7.59	16.12	25.45	24.40	11.85
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	10.31	23.91	17.93	8.74	20.83	30.27	28.27	13.44
T_8 50% NPK	3.89	9.12	13.45	5.73	6.13	11.86	17.24	8.73
T_9 50% NPK + 50% N through Green Manures	7.46	16.89	15.09	6.58	12.26	20.35	20.39	8.98
T_{10} 50% NPK + 50% N through FYM	8.19	17.71	15.79	6.96	15.58	21.68	21.09	9.79
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	5.19	14.65	12.76	7.45	10.34	17.69	19.69	11.64
T_{12} FYM only @ 10 t/ha	5.69	13.53	14.35	6.58	6.64	14.66	13.84	6.98
SEm ±	0.552	0.736	0.614	0.280	1.534	1.637	1.193	0.597
CD @ 0.05	1.62	2.16	1.81	0.82	4.50	4.83	3.52	1.75
CV (%)	8.94	8.53	7.62	9.13	8.16	9.52	8.62	9.18

Table 4: Effect of long-term use of inorganic fertilizers, organic manures and their combination on phosphorus uptake (kg ha^{-1}) by rice

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	2.75	6.71	7.83	2.19	3.39	7.85	8.95	3.72
T_2 100% RDF	10.71	18.69	17.43	9.81	15.08	23.18	21.52	10.15
T_3 100% NK	6.25	15.99	13.29	9.13	12.95	17.93	20.22	8.36

T_4	100% PK	6.09	14.65	12.10	6.11	8.09	16.56	14.26	7.07
T_5	100% NP	6.14	14.96	14.51	7.58	11.02	15.38	18.65	7.56
T_6	100% RDF + $ZnSO_4$ @ 40 kg/ha	11.98	21.11	19.39	9.98	17.09	25.29	24.71	10.99
T_7	100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	13.76	25.58	19.64	11.23	21.26	28.55	27.74	12.79
T_8	50% NPK	4.48	9.76	12.13	6.09	6.49	12.14	17.31	6.36
T_9	50% NPK + 50% N through Green Manures	9.58	18.79	15.58	9.21	12.58	21.16	21.45	8.81
T_{10}	50% NPK + 50% N through FYM	10.49	19.68	16.29	7.66	15.61	22.45	21.62	9.65
T_{11}	50% NPK + 25% N through GM + 25% N through FYM	5.72	15.56	13.38	8.04	10.22	18.26	21.34	10.08
T_{12}	FYM only @ 10 t/ha	6.44	13.55	13.51	6.67	6.69	16.24	13.98	7.64
SEm ±		0.580	1.347	0.733	0.372	1.367	1.299	0.948	0.685
CD @ 0.05		1.70	3.95	2.15	1.09	4.01	3.81	2.78	2.01
CV (%)		8.79	9.48	7.91	8.99	7.68	7.19	6.84	7.28

Table 5: Effect of long-term use of inorganic fertilizers, organic manures and their combination on potassium uptake (kg ha^{-1}) by *r*ice

Treatments		*Kharif* (2016)				*Rabi* (2017)			
		Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
				Grain	Straw			Grain	Straw
T_1	Control	16.92	56.31	16.09	42.32	25.49	61.83	19.37	57.92
T_2	100% RDF	54.28	145.10	32.95	121.64	92.84	182.65	42.33	152.29
T_3	100% NK	45.69	134.12	29.44	110.49	82.59	158.25	42.00	139.84
T_4	100% PK	32.84	106.79	23.53	85.92	54.32	139.20	32.19	111.24
T_5	100% NP	38.29	112.52	31.39	87.34	70.91	129.97	39.75	118.12
T_6	100% RDF + $ZnSO_4$ @ 40 kg/ha	57.84	162.35	42.98	122.15	107.94	194.46	46.74	170.28
T_7	100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	65.72	177.29	44.27	144.23	114.48	216.25	51.00	186.79
T_8	50% NPK	29.84	101.06	31.28	75.15	53.59	122.54	33.85	105.52
T_9	50% NPK + 50% N through Green Manures	50.38	139.26	28.04	113.95	75.92	169.07	39.19	141.42
T_{10}	50% NPK + 50% N through FYM	51.82	140.64	28.90	116.54	88.42	178.44	40.14	144.15
T_{11}	50% NPK + 25% N through GM + 25% N through FYM	41.15	131.04	36.30	98.96	75.13	145.53	38.91	135.69
T_{12}	FYM only @ 10 t/ha	37.83	110.19	32.10	82.72	44.92	125.70	31.15	97.79
SEm ±		2.557	5.248	1.986	5.169	3.239	6.836	2.63	6.533
CD @ 0.05		7.50	15.49	5.36	15.16	9.50	19.31	7.32	19.16
CV (%)		9.35	9.51	10.19	7.68	11.19	10.18	9.46	9.15

Table 6: Effect of long-term use of inorganic fertilizers, organic manures and their combination on potassium uptake (kg ha^{-1}) by rice

Treatments		*Kharif* (2017)				*Rabi* (2018)			
		Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
				Grain	Straw			Grain	Straw
T_1	Control	20.64	54.03	13.91	42.41	26.16	63.66	19.21	57.66
T_2	100% RDF	64.25	149.27	34.30	120.61	95.29	179.50	42.93	156.01
T_3	100% NK	50.16	136.02	26.51	112.29	84.41	157.99	42.49	143.02
T_4	100% PK	33.72	107.09	22.02	87.19	55.16	134.72	32.52	112.05
T_5	100% NP	40.75	111.93	29.91	84.64	72.45	117.91	39.86	114.51
T_6	100% RDF + $ZnSO_4$ @ 40 kg/ha	72.15	170.29	39.85	130.36	111.36	192.56	47.96	172.24
T_7	100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	82.92	183.09	42.49	148.92	117.71	205.03	52.34	186.65
T_8	50% NPK	32.19	101.99	27.20	75.84	54.59	118.03	36.81	104.81
T_9	50% NPK + 50% N through Green Manures	58.25	142.73	29.57	118.53	75.74	169.61	40.84	150.56
T_{10}	50% NPK + 50% N through FYM	61.75	146.31	33.07	120.53	90.06	173.50	38.71	148.94
T_{11}	50% NPK + 25% N through GM + 25% N through FYM	43.41	132.45	35.05	102.74	76.62	146.22	40.12	138.72
T_{12}	FYM only @ 10 t/ha	41.25	113.89	30.68	86.23	46.81	127.01	30.95	103.53
SEm ±		3.451	5.836	1.709	6.182	2.792	6.257	2.175	5.963
CD @ 0.05		10.12	16.89	4.50	18.13	8.19	18.35	6.38	17.49
CV (%)		11.92	9.52	8.42	7.88	7.63	8.19	7.19	8.64

Conclusions

Data regarding all macro and micro nutrient uptake by rice crop was higher with the application of 100% RDF in combination with $ZnSO_4$ and FYM @ 5t ha^{-1} and it was significantly superior over other treatments but however it was on par with that of application of 100% RDF along with $ZnSO_4$ @ 40 kg ha^{-1} during both the years of the study in *kharif* and *rabi*. The application of 50% NPK + 50% N through FYM was on par with 100% RDF. Uptake of all the macronutrients was markedly influenced by the treatments and the application of 100% RDF in combination with $ZnSO_4$ and FYM @ 5t ha^{-1} recorded superior values than other treatments.

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