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Effect of long-term use of inorganic fertilizers, organic manures and their combination on micronutrient uptake under rice-rice cropping system

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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 *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 indicated that micronutrient uptake highest (except zinc) was observed with application of 100% RDF + $ZnSO_4$ +FYM (T_7). However, it was on par with application of only application of 10t/ha FYM, 50% NPK + 50% N through FYM and 50% NPK + 25% N through FYM + 25% N through green manures. The zinc uptake was higher in application of 100% RDF + $ZnSO_4$ +FYM @ 5 t ha^{-1} (T_7) which was on par with application of 100% RDF along with $ZnSO_4$ @ 40 kg ha^{-1}.

Keywords: organic manures, inorganics and micronutrients uptake

Introduction
Rice (*Oryza sativa* L.) is the principal food crop of the world, contributing 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) [2]. Rice-rice, the main cropping system in the eastern coast of India, requires heavy amount of plant nutrients that results in decline in net returns per unit area. Soil fertility and productivity in Godavari delta are likely to be affected due to intensive rice monoculture with imbalanced fertilization under excessive use of irrigation water. A declining trend in the productivity of rice even when grown under adequate application of N, P and K was reported by Nambiar and Abrol (1989) [4]. 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) [8]. 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
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. All together there were twelve treatments laid out 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+1/3rdat tillering+1/3rdat 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 uptake of micronutrients of both *kharif* and *rabi* rice. Micronutrient uptake was expressed in g ha^{-1}.

Results and Discussion
Iron uptake
The iron uptake data at tillering, panicle initiation and at harvest stage were statistically computed and furnished in (table 1) at all stages in all the four seasons iron uptake was significantly influenced by different treatments.

At tillering stage the maximum iron uptake (1.57, 2.73, 1.96, 2.84 kg ha^{-1}) was recorded in the treatment T_7, which was significantly superior over all other treatments. The lowest iron uptake (0.49, 0.65, 0.52, 0.66 kg ha^{-1}) was recorded in the treatment T_1 (control). Similar results were observed in *kharif*, *rabi* during both the years of study. At panicle initiation stage the maximum iron uptake (4.18, 4.83, 4.25, 4.68 kg ha^{-1} in *kharif*, *rabi*, 2016-17 and 2017-18, respectively) was recorded in the treatment T_7, which was significantly superior over all other treatments. The lowest iron uptake (0.49, 0.65, 0.52, 0.66 kg ha^{-1}) was recorded in the treatment T_1 (control). Similar results were observed in *kharif*, *rabi* during both the years of study. The iron uptake by straw was ranged from 1.02 to 3.29; 1.45 to 4.15; 1.03 to 3.41; 1.42 to 4.21 kg ha^{-1} during *kharif* and *rabi* seasons of 2016-17 and 2017-18, respectively among different treatments.

The highest iron uptake was observed in 100% RDF +FYM + $ZnSO_4$with 3.29, 4.15, 3.41, 4.21kg ha^{-1}which was significantly superior over remaining all the treatments in all four seasons of study and the lowest in control which was statistically inferior from all the treatments under study. The lowest value of iron uptake was in control and imbalanced fertilizer treatments whereas combined treatments and balanced dose of fertilizer treatments showed the highest value of iron uptake.

There was a significant increase in the Fe concentration and uptake under continuous flooding due to the reduction of higher oxides and hydroxides of Fe into soluble form and thus increased availability of iron. Increase in uptake was due to higher availability of the plant nutrients from the soil reservoir and additional quantity of nutrients supplied by farm yard manure (Sharma and Dixit, 1987) [5]. N application might have enhanced the uptake of iron by changing rhizosphere pH.

Manganese uptake

The highest manganese uptake at tillering stage, was observed in T_7 (100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1}) it was significantly superior over other treatments in *kharif* season. Whereas in *rabi*, the treatment T_7 was significantly superior over remaining treatments but however it was on par with T_6. Lowest (0.178, 0.251, 0.188, 0.259 kg ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18) manganese uptake was observed in untreated control (T_1).

Manganese uptake was ranged from 0.450 to 1.389 in *kharif*,16; 0.508 to 1.713 in *rabi*,17; 0.413 to 1.338 in *kharif*,17; 0.512 to 1.595 kg ha^{-1} in *rabi*,18 at panicle initiation stage. The highest manganese uptake by rice was recorded by the treatment T_7 and it was significantly superior over other treatments but however it was on par with T_6 (100% RDF + $ZnSO_4$) in *kharif* and *rabi* during both the years of study and lowest manganese uptake was observed in untreated control (T_1).

The highest Mn uptake by rice grain (0.305, 0.439, 0.291, 0.478 kg ha^{-1}) and straw (1.256, 1.593, 1.239, 1.645 kg ha^{-1}) was recorded in the treatment $T_7$and it was significantly superior over other treatments but however it was on par with treatment T_6 in *kharif*, *rabi* during both the years of study. Lowest (0.089, 0.103, 0.063, 0.112 kg ha^{-1} and 0.382, 0.537, 0.379, 0.552 kg ha^{-1}) in grain and straw, in *kharif*, *rabi* 2016-17 and 2017-18, respectively) manganese uptake was observed in untreated control (T_1).

The results revealed that the combined treatments increased manganese uptake it might be due to supply of this nutrient through organic manures further these organics might have increased the manganese availability through enhanced mineralization and chelation action which facilitated greater absorption and utilization of manganese. This increased Mn uptake by grain and straw of rice might due to increased Mn content and drymatter accumulation. Similar findings were reported by Kumar and Singh (2010) [3].

Zinc uptake

Data pertaining to effect of organics, inorganics and their combination on Zn uptake by rice at different stages presented in table 5 and 6revealed that there was a significant variation among treatments during both the years of study. It was obvious from the data the highest Zn uptake of rice was observed in the treatment T_7(100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1}) at tillering, panicle initiation, grain and straw at harvesting stage of rice during both the years of study in *kharif* and *rabi*.

At tillering stage the maximum zinc uptake (144.14, 265.41, 190.39, 278.16 g ha^{-1} respectively 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, whereas in *rabi*, the treatment T_7 was on par with T_6 and significantly superior over other treatments. As far as combined treatments (T_7, T_9, T_{10} and T_{11}), the treatment T_7 was significantly superior over T_9, T_{10} and T_{11}. The lowest zinc uptake (34.56, 54.49, 39.42, 54.75 g ha^{-1}, respectively in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18) was recorded in the treatment T_1 (control).

Among the inorganic treatments of NPK (T_2, T_3, T_4, T_5 and T_8), the treatment T_2 was superior over treatments (T_3, T_4, T_5 and T_8).The soil application of zinc sulphate significantly increased the zinc uptake by plants (Prasad and Umar, 1993). Higher Zn uptake under combined application N and $ZnSO_4$ was due to synergistic effect between N and Zn as reported by (Shanmugam and Veeraputhran, 2001).

Zinc uptake was ranged from 84.29 to 336.11 in *kharif*, 16; 113.92 to 420.83 in *rabi*,17; 92.56 to 349.69 in *kharif*,17; 109.61 to 385.83 g ha^{-1} in *rabi*,18) at panicle initiation stage. The highest zinc uptake by rice was recorded by the treatment T_7 which was on par with T_6 (100% RDF + $ZnSO_4$) and significantly superior over remaining treatments during first year study. In second year *rabi*, 2017 the treatment T_7 was significantly superior over remaining all other treatments. Lowest zinc uptake was observed in control (T_1), which was significantly lower compared to all other treatments. Dahdouh *et al*. (1999) [1] found that organic manures played an important role in nutrients solubility and activated physiological and biochemical processes in plant which led to increase of the plant growth and nutrient uptake.

The zinc uptake by straw was ranged from 64.99 to 282.58; 118.89 to 392.45; 77.53 to 301.89; 125.92 to 413.79 g ha^{-1} during four seasons of study among different treatments. The highest zinc uptake was observed in 100% RDF +FYM + $ZnSO_4$(T_7) followed by 100%NPK + $ZnSO_4$ (T_6) and 50% NPK + 50% N through FYM (T_{10}) in *kharif* season. Whereas in *rabi* the treatment T_7 followed by T_6 and T_2. The lowest in control (T_1) which was significantly different from all the treatments under study. Among the combined treatments (T_7, T_9, $T_{10}$and T_{11}), the treatment (T_7) had maximum zinc uptake in rice straw which was significantly superior over T_9, T_{10} and T_{11}. However, the treatments T_9, T_{10} and T_{11} were on par with each other.

Copper uptake

The highest cu uptake by rice at tillering stage was recorded in the treatment T_7 (45.72, 85.61, 50.26, 88.40 g ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18, respectively), which was on par with T_6 and significantly superior over remaining treatments in 2016-17. During the second year study (2017-18) the treatment T_7 was significantly superior over other treatments. Among the combined application of organic and inorganic fertilizer treatments (T_7, T_9, T_{10}, T_{11}), the significantly higher copper uptake was observed with the application of recommended dose of fertilizer (100% RDF) along with $ZnSO_4$ + FYM @ 5 t ha^{-1} (T_7) which was significantly superior over T_9, T_{10} and T_{11}. Among the T_9, T_{10} and T_{11} treatments, the treatment T_9 (50% NPK + 50% N through green manures) and T_{10} (50% NPK + 50% N through FYM) were on par with each other and significantly superior over T_{11} in all the seasons except in *Rabi*, 2018.Lowest cu uptake (9.53, 13.21, 8.85, 13.65 g ha^{-1} in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 respectively was observed in control (T_1).

At panicle initiation stage, among the inorganic treatments of NPK (T_2, T_3, T_4, T_5 and T_8), T_2 was superior over remaining treatments. However the treatments T_4, T_5 and T_8 were on par with each other. The treatments T_6 and T_2 were on par with each other in all the seasons except in *Kharif*, 17.Lowest copper uptake (22.58, 26.59, 18.23, 33.90 g ha^{-1}, in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 respectively was observed in control (T_1). The application of 100% NP and 100%NK treatment recorded decrease in copper uptake, whereas, the decreased was large under control. The highest copper uptake was observed in treatment T_7 (100% RDF+ $ZnSO_4$+ FYM) which was significantly superior over all other treatments in all the seasons except in *kharif* 17. Treatment T_7 was on par with T_6 and significantly superior over rest of the treatments in *kharif* 17.

The highest copper uptake by rice grain (29.31, 39.82, 27.95, 41.89 g ha^{-1}in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 respectively was recorded in the treatment T_7which was on par with the treatment T_6 with produced (27.41, 34.36, 26.43, 39.39 g ha^{-1}in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 respectively and significantly superior over remaining treatments during both the years of study in all the four seasons. These results were in close conformity with the findings of Sriramachandrasekharan (2001) who reported the highest copper uptake with FYM application along with RDF. Lowest (10.91, 13.55, 9.25, 14.09 g ha^{-1}, in *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18 respectively in grain copper uptake was observed in untreated control (T_1).

The copper uptake by straw was ranged from 16.75 to 57.72; 26.54 to 91.86; 16.27 to 55.38; 26.78 to 97.31g ha^{-1} during *kharif*, *rabi* 2016-17 and *kharif*, *rabi* 2017-18. The highest copper uptake was observed in 100% RDF +FYM + $ZnSO_4$ (T_7) followed by 100%NPK + 50% NPK + 50% Nthrough FYM (T_{10}) and 100% RDF + $ZnSO_4$ (T_6) in first year study. Whereas in the treatment T_7 followed by T_6 and T_{10} in *kharif*, 17. In *rabi*, *2018*the treatment T_7 followed by T_9 and T_{10}. Among the combined treatments (T_7, T_9, $T_{10}$and T_{11}), the treatment which received 100% RDF + $ZnSO_4$ + FYM @ 5t/ha (T_7) had maximum copper uptake in rice straw which was on par with T_{10} (50%NPK + 50% N through FYM) significantly superior over T_9 and T_{11} in *kharif* season. Whereas in *rabi* the treatment T_7 was significantly superior over T_9, $T_{10}$and T_{11}. This increase Cu uptake by grain and straw of rice might due to increased Cu content.

Uptake of micronutrients was improved when organic manure was added along with chemical fertilizers. The increase in the uptake of cationic micronutrients with the application of FYM along with inorganic nitrogen might be due to the release of micronutrients on mineralization or production of organic acids during their decomposition which aids in solubilization of insoluble micronutrient compounds in soil or due to supply of natural chelating agents which render it more available (Stevenson and Ardakani, 1972) [7]. Dahdouh, *et al.* (1999) [1] found that organic manures played an important role in nutrients solubility and activated physiological and biochemical processes in plant which led to increase the plant growth and nutrient uptake.

Table 1: Effect of long-term use of inorganic fertilizers, organic manures and their combination on iron 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	0.49	1.35	0.37	1.02	0.65	1.59	0.48	1.45
T_2 100 % RDF	1.34	3.75	0.96	2.93	2.42	4.19	1.28	3.62
T_3 100% NK	1.05	2.95	0.75	2.39	1.76	3.46	0.99	2.98
T_4 100% PK	0.77	2.56	0.65	1.99	1.20	3.05	0.82	2.46
T_5 100% NP	0.98	2.81	0.72	2.36	1.71	2.92	0.93	2.96
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	1.33	3.38	0.90	2.74	2.16	4.02	1.23	3.40
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1.57	4.18	1.03	3.29	2.73	4.83	1.47	4.15
T_8 50% NPK	0.75	2.39	0.68	1.85	1.32	2.79	0.83	2.39
T_9 50% NPK + 50 % N through Green Manures	1.16	3.25	0.86	2.43	1.76	3.84	1.09	3.17
T_{10} 50% NPK + 50 % N through FYM	1.25	3.30	0.92	2.78	2.00	3.98	1.14	3.35
T_{11} 50% NPK + 25 % N through GM + 25 % N through FYM	1.03	3.19	0.83	2.49	1.84	3.51	1.12	3.18
T_{12} FYM only @ 10 t/ha	0.95	2.66	0.76	2.15	1.08	3.25	0.79	2.33
SEm ±	0.061	0.140	0.017	0.119	0.099	0.188	0.041	0.174
CD @ 0.05	0.18	0.41	0.05	0.35	0.29	0.55	0.12	0.51
CV (%)	7.35	8.12	7.96	7.54	7.25	7.93	8.54	8.16

Table 2: Effect of long- term use of inorganic fertilizers, organic manures and their combination on iron 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	0.52	1.36	0.37	1.03	0.66	1.64	0.48	1.42
T_2 100 % RDF	1.66	3.74	0.92	2.84	2.53	4.17	1.34	3.65
T_3 100% NK	1.10	3.01	0.68	2.39	1.77	3.50	1.02	3.05
T_4 100% PK	0.83	2.54	0.62	2.02	1.24	2.95	0.83	2.47
T_5 100% NP	1.05	2.81	0.66	2.24	1.77	2.86	0.95	2.88
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	1.56	3.4	0.93	2.87	2.17	3.98	1.25	3.44
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1.96	4.25	1.12	3.41	2.84	4.68	1.52	4.21
T_8 50% NPK	0.79	2.30	0.59	1.82	1.34	2.70	0.82	2.37
T_9 50% NPK + 50 % N through Green Manures	1.37	3.24	0.84	2.55	1.76	3.87	1.17	3.36
T_{10} 50% NPK + 50 % N through FYM	1.46	3.34	0.96	2.84	2.08	3.88	1.19	3.48
T_{11} 50% NPK + 25 % N through GM + 25 % N through FYM	1.08	3.13	0.80	2.51	1.89	3.50	1.15	3.27
T_{12} FYM only @ 10 t/ha	0.98	2.68	0.70	2.19	1.15	3.12	0.84	2.38
SEm ±	0.082	0.153	0.051	0.164	0.092	0.170	0.048	0.177
CD @ 0.05	0.24	0.45	0.15	0.48	0.27	0.50	0.14	0.52
CV (%)	8.25	7.24	8.19	7.96	8.16	7.25	8.79	7.05

Table 3: Effect of long-term use of inorganic fertilizers, organic manures and their combination on manganese 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	0.178	0.450	0.089	0.382	0.251	0.508	0.103	0.537
T_2 100 % RDF	0.539	1.111	0.239	1.071	0.862	1.354	0.295	1.291
T_3 100% NK	0.405	0.965	0.198	0.859	0.718	1.117	0.239	1.109
T_4 100% PK	0.294	0.823	0.168	0.693	0.489	1.000	0.188	0.883
T_5 100% NP	0.378	0.892	0.189	0.834	0.689	1.006	0.218	1.091
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	0.549	1.210	0.255	1.121	1.029	1.487	0.379	1.452
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	0.638	1.389	0.305	1.256	1.159	1.713	0.439	1.593
T_8 50% NPK	0.279	0.785	0.155	0.662	0.508	0.899	0.175	0.863
T_9 50% NPK + 50 % N through Green Manures	0.483	1.095	0.251	0.992	0.729	1.317	0.298	1.229
T_{10} 50% NPK + 50 % N through FYM	0.491	1.122	0.248	1.062	0.813	1.338	0.307	1.227
T_{11} 50% NPK + 25 % N through GM + 25 % N through FYM	0.396	1.035	0.209	0.921	0.723	1.133	0.279	1.214
T_{12} FYM only @ 10 t/ha	0.374	0.876	0.196	0.769	0.432	0.983	0.195	0.873
SEm ±	0.024	0.078	0.010	0.046	0.048	0.102	0.027	0.061
CD @ 0.05	0.07	0.23	0.03	0.13	0.14	0.30	0.08	0.18
CV (%)	9.88	9.84	9.49	8.97	8.46	11.06	9.16	11.96

Table 4: Effect of long-term use of inorganic fertilizers, organic manures and their combination on manganese 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	0.188	0.413	0.063	0.379	0.259	0.512	0.112	0.552
T_2 100 % RDF	0.578	1.065	0.229	0.972	0.876	1.281	0.339	1.383
T_3 100% NK	0.429	0.912	0.142	0.833	0.733	1.082	0.256	1.149
T_4 100% PK	0.301	0.774	0.114	0.681	0.498	0.921	0.209	0.889
T_5 100% NP	0.389	0.840	0.138	0.787	0.696	0.853	0.248	1.088
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	0.631	1.245	0.246	1.108	1.069	1.448	0.419	1.498
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	0.779	1.338	0.291	1.239	1.209	1.595	0.478	1.645
T_8 50% NPK	0.283	0.671	0.109	0.661	0.502	0.856	0.175	0.871
T_9 50% NPK + 50 % N through Green Manures	0.549	1.024	0.201	0.989	0.735	1.291	0.354	1.358
T_{10} 50% NPK + 50 % N through FYM	0.564	1.053	0.208	1.021	0.839	1.258	0.379	1.385
T_{11} 50% NPK + 25 % N through GM + 25 % N through FYM	0.392	0.942	0.169	0.893	0.735	1.101	0.346	1.296
T_{12} FYM only @ 10 t/ha	0.375	0.823	0.139	0.773	0.456	0.969	0.241	0.925
SEm ±	0.044	0.075	0.017	0.051	0.055	0.072	0.020	0.048
CD @ 0.05	0.13	0.22	0.05	0.15	0.16	0.21	0.06	0.14
CV (%)	11.68	11.87	8.63	9.97	7.69	8.15	7.25	10.69

Table 5: Effect of long-term use of inorganic fertilizers, organic manures and their combination on zinc uptake (g ha^{-1}) by rice

Treatments	*Kharif*(2016)				*Rabi* (2017)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	34.56	84.29	46.08	64.99	54.49	113.92	62.51	118.89
T_2 100% RDF	102.98	240.21	129.86	204.45	206.91	354.45	193.09	323.01
T_3 100% NK	75.87	191.83	98.89	160.09	162.19	269.01	151.31	259.18
T_4 100% PK	56.26	161.01	85.19	127.45	106.95	237.52	113.39	199.97
T_5 100% NP	68.30	172.55	96.28	151.55	148.81	218.84	130.51	254.91
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	117.20	294.92	158.19	238.69	245.19	378.19	223.14	352.38
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	144.14	336.11	180.19	282.58	265.41	420.83	263.79	392.45
T_8 50% NPK	44.93	139.57	88.25	119.85	107.53	207.97	110.51	200.29
T_9 50% NPK + 50% N through Green Manures	98.75	244.69	136.99	185.06	160.35	310.59	167.39	280.49
T_{10} 50% NPK + 50% N through FYM	105.30	240.52	132.15	205.76	184.75	325.31	173.61	287.19
T_{11} 50% NPK + 25 % N through GM + 25% N through FYM	78.87	215.21	109.56	173.85	166.5	282.25	169.74	289.91
T_{12} FYM only @ 10 t/ha	71.19	182.18	103.39	145.37	96.35	259.44	115.49	205.32
SEm ±	8.579	15.237	7.556	12.997	8.313	14.283	12.145	13.451
CD @ 0.05	25.16	44.69	22.16	38.12	24.38	41.89	35.62	39.45
CV (%)	7.59	8.29	12.19	9.57	12.21	9.46	9.82	8.47

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

Treatments	*Kharif*(2017)				*Rabi* (2018)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	39.42	92.56	44.95	77.53	54.75	109.61	61.62	125.92
T_2 100% RDF	129.51	257.84	143.19	222.69	213.92	338.09	213.93	349.49
T_3 100% NK	92.98	215.32	99.12	178.89	170.19	256.75	168.22	274.83
T_4 100% PK	65.18	175.91	79.58	143.35	110.24	216.53	122.84	212.35
T_5 100% NP	82.39	194.14	89.15	163.82	150.72	205.09	146.23	267.12
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	153.91	305.18	176.03	264.62	258.24	354.54	241.35	371.12
T_7 100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	190.39	349.69	199.32	301.89	278.16	385.83	283.89	413.79
T_8 50% NPK	57.23	154.31	75.39	137.65	108.99	193.49	118.68	204.23
T_9 50% NPK + 50% N through Green Manures	120.08	253.87	130.12	214.82	162.51	302.06	192.35	311.30
T_{10} 50% NPK + 50 % N through FYM	129.89	249.46	148.89	230.55	192.90	306.04	192.89	314.89
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	87.31	225.03	116.21	201.02	172.89	270.02	186.23	307.75
T_{12} FYM only @ 10 t/ha	82.42	197.84	98.71	169.31	102.75	236.15	130.89	223.29
SEm ±	11.316	16.305	8.568	13.717	10.324	12.077	11.586	12.050
CD @ 0.05	33.19	47.82	25.13	40.23	30.28	35.42	33.98	35.34
CV (%)	8.67	7.86	9.83	8.65	10.38	9.64	8.25	7.28

Table 7: Effect of long-term use of inorganic fertilizers, organic manures and their combination on copper uptake (g ha^{-1}) by rice

Treatments	*Kharif*(2016)				*Rabi* (2017)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	9.53	22.58	10.91	16.75	13.21	26.59	13.55	26.54
T_2 100% RDF	36.48	68.63	25.39	48.79	65.42	98.60	31.39	70.48
T_3 100% NK	25.71	56.93	22.59	43.47	47.09	76.51	27.94	57.39
T_4 100% PK	19.10	44.44	19.19	32.56	31.42	68.21	23.09	48.63
T_5 100% NP	22.59	48.37	21.79	39.53	44.49	69.45	27.12	57.10
T_6 100 % RDF + $ZnSO_4$ @ 40 kg/ha	37.98	78.12	27.41	50.61	74.92	102.53	34.36	74.54
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	45.72	93.32	29.31	57.72	85.61	129.06	39.82	91.86
T_8 50% NPK	17.31	42.79	19.75	32.12	32.19	60.40	22.35	45.39
T_9 50% NPK + 50% N through Green Manures	35.95	70.58	25.69	46.61	55.91	100.39	30.38	72.12
T_{10} 50% NPK + 50% N through FYM	37.19	74.64	26.75	51.35	65.31	103.48	29.04	76.54
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	26.69	63.21	23.15	42.59	52.69	84.58	28.75	59.79

T_{12} FYM only @ 10 t/ha	24.51	55.94	22.23	36.10	29.13	66.91	21.09	48.30
SEm ±	2.932	3.273	0.750	2.387	3.815	8.033	1.875	2.898
CD @ 0.05	8.60	9.64	2.22	7.03	11.19	23.56	5.52	8.55
CV (%)	12.18	10.17	9.62	10.13	9.13	11.67	9.45	11.93

Table 8: Effect of long-term use of inorganic fertilizers, organic manures and their combination on copper uptake (g ha^{-1}) by rice

Treatments	*Kharif*(2017)				*Rabi* (2018)			
	Tillering	Panicle Initiation	Harvest		Tillering	Panicle Initiation	Harvest	
			Grain	Straw			Grain	Straw
T_1 Control	8.85	18.23	9.25	16.27	13.65	33.9	14.09	26.78
T_2 100% RDF	37.39	67.29	27.51	45.08	67.69	104.29	33.79	70.96
T_3 100% NK	23.78	56.09	18.51	39.49	48.53	88.39	30.52	61.92
T_4 100% PK	16.09	46.22	15.08	32.28	31.81	74.01	24.59	50.19
T_5 100% NP	20.62	49.85	16.82	37.65	44.94	72.56	29.32	59.59
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	40.29	76.54	26.43	52.24	77.49	114.31	39.39	76.86
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	50.26	80.48	27.95	55.38	88.40	139.11	41.89	97.31
T_8 50% NPK	15.35	40.70	14.63	29.52	32.66	68.51	23.09	47.99
T_9 50% NPK + 50% N through Green Manures	35.09	66.95	23.15	46.84	56.18	114.12	32.69	82.09
T_{10} 50% NPK + 50% N through FYM	37.68	69.23	23.87	49.88	67.29	113.8	32.28	81.77
T_{11} 50% NPK + 25% N through GM + 25% N through FYM	24.11	59.41	18.89	42.63	57.31	102.03	31.56	78.57
T_{12} FYM only @ 10 t/ha	22.21	52.28	16.94	37.29	30.59	78.49	24.09	55.9
SEm ±	2.864	2.898	0.682	2.216	3.454	5.053	1.637	3.341
CD @ 0.05	8.42	8.56	2.01	6.53	10.13	14.82	4.81	9.85
CV (%)	11.98	11.89	8.13	11.19	8.26	7.68	9.16	7.18

Conclusions

Micronutrient uptake the highest (except zinc) was observed with application of 100% RDF + $ZnSO_4$ +FYM (T_7). However, it was on par with application of only application of 10t/ha FYM, 50% NPK + 50% N through FYM and 50% NPK + 25% N through FYM + 25% N through green manures. The zinc uptake was higher in application of 100% RDF + $ZnSO_4$ +FYM @ 5 t ha^{-1} (T_7) which was on par with application of 100% RDF along with $ZnSO_4$@ 40 kg ha^{-1}.

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