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Effect of long-term use of inorganic fertilizers, organic manures and their combination on micronutrient content in soil 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 at initial, tillering, panicle initiation and at harvest stage, significantly the highest available micronutrients in soil were recorded with application of 100% NPK + $ZnSO_4$ +FYM (T_7). Compared to organics and inorganic sources alone (T_{12}, T_3, T_4 and T_5), their combinations (T_7, T_9, T_{10} and T_{11}) recorded higher values of available nutrients in soil. The treatments T_9 (50% NPK + 50% N through green manures), T_{10} (50% NPK + 50% N through FYM) and T_{11} (50% NPK + 25% N through FYM + 25% N through green manures) were on par with each other in all four seasons of study.

Keywords: Organic manures, inorganics and available micronutrients

Introduction
Many tropical soils are poor in nutrients and rely on the recycling of nutrients from soil organic matter to improve and maintain crop productivity. Intensive cultivation, growing of exhaustive crops, use of imbalanced and inadequate fertilizers, restricted use of organic manures has made the soils not only deficient in nutrients but also deteriorate soil health resulting decline in crop response to recommended dose of NPK fertilizers. To supply recommended dose of nutrients, large quantities of organic material is needed and also slow release of plant nutrients upon decomposition from organic material deprive crop growth. Under such conditions integrated plant nutrient management assumes greater significance and plays a vital role in maintenance of soil health and sustainable productivity.

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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 (Anonymous, 2001). 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) [1]. Continuous use of high level of chemical fertilizers had lead to soil degradation problems, which also proved detrimental to soil health.

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 percent recommended dose of NPK, 100 percent recommended dose of NK, 100 percent recommended dose of PK, 100 percent recommended dose of NP, 100 percent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha, 100 percent recommended dose of

NPK+$ZnSO_4$ @ 40 kg/ ha + FYM @ 5 t ha^{-1}, 50 percent 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 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 ($1/3^{rd}$ basal+$1/3^{rd}$ at tillering+$1/3^{rd}$ 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 available micronutrients of both *kharif* and *rabi* rice.

Results and discussion

Micronutrient status of soil

Available micronutrient status of soil was significantly influenced by long-term use of different organics, inorganics and their combination during both the years of the study.

Iron

The data pertaining to the available iron content revealed a significant influence of different nutrient management practices or options on available iron content in soil. At initial stage, available iron content in *kharif* and *rabi* seasons ranged from 6.13 to 9.83, 5.70 to 10.75 and 5.81 to 10.23; 5.61 to 10.91 (mg kg^{-1}). The highest available iron content was observed in T_7 (100% RDF+ $ZnSO_4$ +FYM @ 5 t ha^{-1}) it was significantly superior over other treatments but however it was on par with treatment T_{10} (50% NPK + 50% N through FYM) and T_{12} (FYM only 10t/ha) and the lowest available iron was observed in control (T_1) in both the seasons.

At tillering, panicle initiation stage, the highest available iron was observed in T_7 (100% RDF+FYM @ 5 t ha^{-1} + $ZnSO_4$) which was significantly superior over other treatments but however it was on par with T_{10} and T_{12} in *kharif* season. Whereas in *rabi*, the treatment T_7 was significantly superior over other treatments but however on par with $T_{10,}$ T_{11}, T_{12}. The lowest (6.02, 5.68 and 5.80, 5.53, mg kg^{-1}) available iron was observed in control (T_1) in both the seasons.

The available Fe in soil was increased to a small degree with application of $ZnSO_4$ but not to significant level. The most intriguing correlation of Zn and Fe might be due to their similar nutrient uptake and transporting system. Increase in available Fe with the application of Zn fertilizer might be due to lowering of pH and thereby to increasing the solubility of metallic elements (Prasad *et al*., 2010) [5].

The available iron content increased up to tillering stage and slightly decreased at harvest in all the treatments in both *kharif* and *rabi* during both the years of study.

Maintaining the soil at higher moisture levels increased the available iron content to a great extent on account of development of anaerobic conditions (Venkata subrahmanyam and Mehta, 1975) [10]. The increase might also be due to the action of higher oxides of Fe to soluble forms (Singh *et al*., 1999) [8] reported that the action of chelating agents were increased the availability and the release of Fe from the added organic matter as a result of decomposition. The increase in iron availability was mainly due to the transformation of iron from ferric Fe^{3+} to ferrous Fe^{2+} state in soils under submerged conditions.

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

Manganese

The perusal of data indicated that DTPA-extractable Mn in different treatments at different crop growth stages tended to increase compared to its initial values, except in the control plot where it decreased from 5.78 to 4.82 mg kg^{-1}. An increase in DTPA-extractable Mn may be attributed to the reduction of Mn^{4+} to Mn^{2+} accompanied by an increase in its solubility under submerged conditions and the chelating action of organic manures.

At initial stage, among the different organic sources, application of FYM in treatments T_7 and T_{12} registered 63.79, 56.75 and 37.88, 35.29% in *kharif* season, 61.04, 53.29 and 70.77, 60.83 percent in *rabi* season, respectively higher DTPA-extractable Mn compared to the control. Lal and Mathur (1989) [4] reported long term application of manure and fertilizer increased DTPA-extractable Mn in soil.

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The higher available Mn in soil was recorded at tillering stage with T_7 (100% RDF+ $ZnSO_4$ +FYM @ 5 t ha^{-1}) it was significantly superior over other treatments but however it was on par with T_{10} (50% NPK + 50% N through FYM), T_{11} (50% NPK + 25% N through FYM + 25% N through green manures) and T_{12} (FYM @ 10t/ha). The lowest available manganese was observed in control. Similar results were observed during both the years of study in *kharif* and *rabi*.

In both *kharif* and *rabi* seasons at panicle initiation stage, the available manganese in soil was ranged from 5.32 to 10.19 ; 5.09 to 10.69 and 5.12 to 10.41; 4.92 to 10.89 mg kg^{-1} in different treatments. The highest available manganese content was observed in *kharif* and *rabi* seasons, respectively with application of 100% RDF+ $ZnSO_4$ + FYM @ 5 t ha^{-1} (T_7) it was significantly superior over other treatments but however it was on par with $T_{9,}$ T_{10}, T_{11} and T_{12} in *kharif*. Where as in *rabi* the treatment T_7 was on par with T_{10} and T_{12} and significantly superior over remaining treatments. The lowest available manganese content was observed at both the seasons in control (T_1).

Close observation of the data indicated that the available Mn status at harvest of rice crop was increased over initial status in the organic amended and inorganic fertilizer treatments whereas, the treatment (T_1) control alone could not able to increase the available Mn over initial. The significantly highest available Mn was recorded in the treatment T_7 with the values of 8.34, 8.64 and 8.49, 8.97 mg kg^{-1} it was significantly superior over other treatments but however it was on par with treatment T_{12} with the values of 7.94, 8.18 and 8.09, 8.83 mg kg^{-1} during first and second year of *kharif* and *rabi*, respectively). The lowest available manganese content was observed in control (T_1) in both the years of study.

Application of FYM comparatively recorded the higher concentration of manganese. The increase in manganese availability in soil might be due to reduction of Mn^{4+} to Mn^{2+} resulting in an increase of concentration on DTPA-Mn. Singh *et al*. (1999) [8] reported that increase in manganese content might be attributed to the release of Mn from FYM during its decomposition or due to dissolution of native Mn from soil (Veeranagappa *et al*. 2011) [9].

Zinc

The data revealed that available zinc decreased up to harvesting stage in the experimental treatments (control, only fertilizer treatments (T_2, T_3, T_4, T_5 and T_8) in both *kharif* and *rabi* seasons. This may be attributed to the higher uptake of Zn associated with the application of RDF. The lowest available zinc status was observed at the unfertilized control. Whereas, the available zinc status of soil was also found to be lowest but it was above the critical level of zinc (0.8 mg kg^{-1}) under all the treatments.

At initial stage, available zinc content in *kharif* and *rabi* seasons was ranged from 0.96 to 2.23; 0.87 to 2.52; 0.91 to 2.40; 0.85 to 2.51 mg kg^{-1} in different treatments. The highest soil available zinc was observed in treatment T_7 (100% RDF+FYM @ 5t/ha +ZnSO4 @ 40 kg ha^{-1}) and it was significantly superior over all other treatments but however it was on par with treatment T_6 (100% RDF + ZnSO4 @ 40 kg ha^{-1}) in *kharif*. During *rabi*, the treatment T_7 was significantly superior over all other treatments but however it was on par with T_6, T_9, T_{10} and T_{11}. The lowest available zinc content was observed in control.

Increase in DTPA extractable zinc in inorganic treatments might be due to synergistic effect between nitrogen and zinc. The zinc enriched treatments (T_7, T_6) showed increased Zn content of soil, which was attributed to the enrichment of organic manure with application of fertilizer zinc, which might have supplied additional Zn to the soil pool. This was in accordance with the findings of Devarajan and Krishnasamy (1996) [2].

At tillering stage, the available zinc content observed was ranged from 0.95 to 2.62; 0.86 to 2.85 and 0.90 to 2.76; 0.84 to 2.81 mg kg^{-1} in *kharif* and *rabi* seasons. The highest available zinc was observed with treatment T_7, which received 100% RDF+$ZnSO_4$ +FYM @ 10 t ha^{-1} and it was significantly superior over all other treatments but however it was on par with treatment T_6 (100% RDF + ZnSO4 @ 40 kg ha^{-1}) in *kharif* and *rabi* during both the years of study. The lowest available copper was observed in control (T_1). Combined organic and inorganic treatments (T_9, T_{10} and T_{11}), were on par with each other.

At harvesting stage, available zinc content in *kharif* and *rabi* seasons ranged from 0.91 to 2.41, 0.85 to 2.59 and 0.88 to 2.53; 0.83 to 2.58 mg kg^{-1} in different treatments, respectively. The highest available zinc content was observed in T_7 (100% RDF+ $ZnSO_4$ +FYM @ 5 t ha^{-1}) it was significantly superior over other treatments but however it was on par with T_6 (100% RDF + ZnSO4 @ 40 kg ha^{-1}) and T_{10} (50% NPK + 50% N through FYM). The lowest available zinc was observed in control (T_1) both the seasons. Similar results were observed in both *kharif* and *rabi* during both the years of study.

Among the inorganic treatments the treatment T_6 (100% RDF+ $ZnSO_4$) recorded the highest available zinc and it was significantly superior over all other inorganic treatments (T_2, T_3, T_4, T_5 and T_8). The treatment T_3, T_4 and T_5 were on par with each other and significantly superior over T_8. Similar results were observed in at all the stages of crop growth in *kharif* and *rabi* during both the years of study.

Copper

The soil available copper data at initial, tillering, panicle initiation and harvest stage was statistically analyzed. At initial, tillering, panicle initiation and harvest stages available copper was significantly influenced by different nutrient management options. Combined application of 100% RDF with FYM + $ZnSO_4$ (T_7), recorded highest available copper in soil.

At initial stage, available copper content in *kharif* and *rabi* seasons were ranged from 0.52 to 1.94, 0.45 to 1.99 and 0.49 to 1.95, 0.41 to 2.01 mg kg^{-1} in different treatments. The highest available copper content was observed in T_7 (100% RDF+ $ZnSO_4$ +FYM @ 5 t ha^{-1}) and it was significantly superior over other treatments but however it was on par with treatments T_{10} (50% NPK + 50% N through FYM) and T_{12} (FYM @ 10t/ha). The lowest available copper content was observed in control (T_1). However, in view of 0.2 mg kg^{-1} critical level of Cu in soil, it was adequate for crop production in all the treatments. Similar results were obtained during both the years of study in *kharif* and *rabi*.

The organic matter present in the soil increased the availability of Cu in soils due to the formation of soluble complexing agents resulting decrease in the fixation and precipitation of Cu in soils. Greval *et al.* (1999) [3] observed that the amount of exchangeable Cu increased with an increase in the organic matter content of the soils and existence of significant positive correlation between organic matter and exchangeable Cu.

In both the *kharif* and *rabi* seasons, at tillering stage, available copper was ranged from 0.51 to 3.24, 0.44 to 3.32 and 0.49 to 3.35, 0.40 to 3.49 mg kg^{-1} in different treatments. The highest available copper content was observed in T_7 (application of 100% RDF+ $ZnSO_4$ + FYM @ 5 t ha^{-1}) which was significantly superior over other treatments but however it was on par with treatment T_{10}, T_{12}. The lowest available copper was observed in control (T_1). Similar results were obtained during both the years of study in *kharif* and *rabi*.

At harvest stage, the available Cu content observed was ranged from 0.50 to 1.96; 0.42 to 2.04 and 0.46 to 1.99; 0.39 to 2.13 mg kg^{-1} in *kharif* and *rabi* seasons. The highest available copper was with T_7, which received 100% RD of NPK+$ZnSO_4$ +FYM @ 10 t ha^{-1} it was significantly superior over other treatments but however it was on par with treatment T_{10} and T_{12}. The lowest available copper was observed in control (T_1). Similar results were observed in both the years of study in *kharif* and *rabi* season. The treatments, T_9, T_{10} and T_{11} were on par with each other.

Among the inorganic treatments, the treatment T_6 was recorded highest available copper and it was significantly superior over T_8 but however it was on par with treatment T_2, T_3, T_4, T_5 in *kharif* season. Whereas in *rabi*, the treatment T_6 was recorded highest available copper and it was significantly superior over T_3, T_4, T_5 and T_8 but however it was on par with treatment T_2. Similar results were observed in both the years of study in *kharif* and *rabi* season at all stages during crop growth period.

The increase in available micronutrients status of soils in organically treated plots might be due to addition of micronutrients through FYM and release of chelating agents from organic matter decomposition which might have prevented micronutrients from fixation, precipitation, oxidation and leaching (Sharma *et al.*, 2001) [7]. Reduction in micronutrient contents in inorganic treatments can be attributed to non replenishment of micronutrients through chemical fertilizers.

Table 1: Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil available iron (mg kg^{-1})

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	6.13	6.02	5.93	5.83	5.81	5.80	5.74	5.72
T_2 100% RDF	8.19	11.85	9.19	8.43	8.31	12.54	9.58	8.51
T_3 100% NK	7.65	10.63	8.05	7.84	7.83	11.16	9.16	7.97
T_4 100% PK	7.34	10.14	8.16	7.69	7.64	11.25	9.21	7.86
T_5 100% NP	7.43	10.09	8.34	7.58	7.43	10.93	9.19	7.64
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	8.29	12.01	9.32	8.43	8.41	12.63	9.87	8.53
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	9.83	13.52	11.36	10.41	10.23	14.19	11.96	10.78
T_8 50% NPK	6.98	9.13	7.43	7.04	7.01	9.16	8.34	7.34
T_9 50% NPK + 50% N Through Green Manures	8.35	12.51	9.54	8.59	8.26	12.08	10.61	8.53
T_{10} 50% NPK + 50% N Through FYM	9.34	12.93	10.43	9.59	9.38	13.96	10.75	9.61
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	8.96	12.36	10.01	9.11	9.02	13.04	10.96	9.27
T_{12} FYM only @ 10 t/ha	9.63	13.15	11.09	9.85	9.49	14.08	11.18	9.84
SEm ±	0.290	0.314	0.348	0.426	0.409	0.406	0.447	0.508
CD @ 0.05	0.85	0.92	1.02	1.25	1.20	1.19	1.31	1.49
CV (%)	7.12	8.96	9.13	7.84	8.79	7.51	9.34	7.16

Table 2: Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil available iron (mg kg^{-1})

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	5.70	5.68	5.65	5.64	5.61	5.53	5.51	5.49
T_2 100% RDF	8.49	13.01	9.92	8.63	8.61	13.32	10.92	8.98
T_3 100% NK	7.95	12.12	8.79	7.99	7.91	12.91	10.16	8.62
T_4 100% PK	7.83	12.08	8.54	7.91	7.83	13.01	10.03	8.03
T_5 100% NP	7.61	12.01	8.62	7.74	7.62	11.92	9.89	8.16
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	8.51	13.09	10.19	8.71	8.69	14.06	11.02	9.01
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	10.75	14.73	11.98	10.94	10.91	15.91	13.32	10.84
T_8 50% NPK	7.14	11.63	8.81	7.39	7.23	9.92	8.32	7.32
T_9 50% NPK + 50% N Through Green Manures	8.48	13.49	10.38	8.77	8.71	12.86	10.91	9.32
T_{10} 50% NPK + 50% N Through FYM	9.53	13.96	10.92	9.84	9.79	13.92	11.21	10.01
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	9.24	13.79	10.38	9.69	9.52	13.72	11.16	9.80
T_{12} FYM only @ 10 t/ha	9.81	14.05	11.17	9.97	9.83	14.78	12.86	10.53
SEm ±	0.518	0.327	0.372	0.419	0.389	0.430	0.484	0.351
CD @ 0.05	1.52	0.96	1.09	1.23	1.14	1.26	1.42	1.03
CV (%)	8.91	7.63	9.49	10.16	8.62	7.49	7.72	8.14

Table 3: Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil available manganese (mg kg^{-1})

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	5.78	5.61	5.32	5.19	5.16	5.14	5.12	5.11
T_2 100% RDF	6.92	12.74	8.76	7.05	7.01	11.56	8.53	7.09
T_3 100% NK	6.62	11.92	7.71	6.73	6.68	10.24	7.11	6.83
T_4 100% PK	6.69	11.63	7.39	6.79	6.62	10.29	7.02	6.72
T_5 100% NP	6.43	11.29	7.42	6.53	6.50	10.16	7.09	6.61
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	7.01	12.98	8.84	7.24	7.22	12.03	8.64	7.39
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	7.97	13.93	10.16	8.34	8.31	14.29	10.41	8.49
T_8 50% NPK	6.08	10.16	6.67	6.36	6.30	9.43	6.22	6.52
T_9 50% NPK + 50% N Through Green Manures	7.28	12.92	8.93	7.49	7.42	12.24	8.86	7.64
T_{10} 50% NPK + 50% N Through FYM	7.54	13.39	9.76	7.83	7.79	13.84	9.82	7.96
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	7.24	13.20	9.18	7.53	7.48	13.08	9.09	7.54
T_{12} FYM only @ 10 t/ha	7.82	13.74	10.09	7.94	7.91	14.02	10.36	8.09
SEm ±	0.198	0.252	0.351	0.228	0.211	0.641	0.467	0.269
CD @ 0.05	0.58	0.74	1.03	0.67	0.62	1.88	1.37	0.79
CV (%)	10.23	11.52	7.18	9.92	9.44	8.49	7.86	9.14

Table 4: Effect of long-term use of inorganic fertilizers, organic manures and their combination on available manganese (mg kg^{-1})

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	5.11	5.10	5.09	5.09	5.03	5.01	4.92	4.82
T_2 100% RDF	7.07	12.31	8.96	7.19	7.02	11.84	8.93	7.98
T_3 100% NK	6.81	12.01	7.62	6.93	6.82	10.85	7.94	7.12
T_4 100% PK	6.68	11.92	7.53	6.85	6.79	10.92	8.04	7.48
T_5 100% NP	6.53	11.83	7.69	6.76	6.63	10.34	8.12	7.62
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	7.28	12.42	9.16	7.59	7.42	12.19	9.14	8.12
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	8.37	14.46	10.69	8.64	8.59	14.96	10.89	8.97
T_8 50% NPK	6.41	10.85	7.18	6.47	6.32	9.92	6.35	7.02
T_9 50% NPK + 50% N Through Green Manures	7.61	13.01	10.03	7.82	7.72	12.93	8.96	8.34
T_{10} 50% NPK + 50% N Through FYM	7.86	13.76	10.16	7.98	7.91	13.91	9.96	8.76
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	7.51	12.89	9.29	7.73	7.68	13.24	9.46	8.49
T_{12} FYM only @ 10 t/ha	8.01	14.29	10.53	8.18	8.09	14.18	10.43	8.83
SEm ±	0.218	0.314	0.464	0.242	0.280	0.382	0.484	0.430
CD @ 0.05	0.64	0.92	1.36	0.71	0.82	1.12	1.42	1.26
CV (%)	7.16	7.51	8.79	9.61	8.13	7.79	8.24	7.34

Table 5: Effect of long-term use of inorganic fertilizers, organic manures and their combination on available zinc (mg kg^{-1})

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	0.96	0.95	0.93	0.91	0.91	0.90	0.89	0.88
T_2 100% RDF	1.81	1.76	1.69	1.66	1.66	1.61	1.56	1.54
T_3 100% NK	1.75	1.67	1.59	1.56	1.55	1.51	1.45	1.42
T_4 100% PK	1.65	1.57	1.47	1.43	1.42	1.38	1.31	1.30
T_5 100% NP	1.67	1.58	1.48	1.44	1.43	1.39	1.32	1.31
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	2.11	2.46	2.30	2.25	2.24	2.61	2.46	2.40
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	2.23	2.62	2.47	2.41	2.40	2.76	2.57	2.53
T_8 50% NPK	1.62	1.54	1.41	1.37	1.36	1.30	1.28	1.24
T_9 50% NPK + 50% N Through Green Manures	1.91	2.23	2.14	2.12	2.12	2.50	2.29	2.25
T_{10} 50% NPK + 50% N Through FYM	1.95	2.26	2.18	2.15	2.14	2.48	2.32	2.28
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	1.90	2.19	2.12	2.08	2.07	2.41	2.28	2.23
T_{12} FYM only @ 10 t/ha	1.87	2.10	2.05	2.02	2.02	2.38	2.24	2.20
SEm ±	0.051	0.063	0.044	0.058	0.061	0.048	0.072	0.065
CD @ 0.05	0.15	0.18	0.13	0.17	0.18	0.14	0.21	0.19
CV (%)	10.5	9.8	8.6	11.9	7.19	8.72	11.59	8.45

Table 6: Effect of long-term use of inorganic fertilizers, organic manures and their combination on available zinc (mg kg^{-1})

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	0.87	0.86	0.85	0.85	0.85	0.84	0.83	0.83
T_2 100% RDF	1.53	1.49	1.44	1.42	1.41	1.39	1.36	1.33
T_3 100% NK	1.41	1.37	1.33	1.30	1.29	1.21	1.17	1.14
T_4 100% PK	1.28	1.23	1.19	1.17	1.15	1.12	1.10	1.05
T_5 100% NP	1.29	1.26	1.22	1.20	1.16	1.13	1.10	1.08
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	2.40	2.71	2.53	2.48	2.46	2.79	2.58	2.51
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	2.52	2.85	2.67	2.59	2.51	2.81	2.63	2.58
T_8 50% NPK	1.23	1.20	1.18	1.16	1.15	1.11	1.09	1.02
T_9 50% NPK + 50% N Through Green Manures	2.25	2.59	2.46	2.42	2.40	2.71	2.43	2.28
T_{10} 50% NPK + 50% N Through FYM	2.27	2.62	2.50	2.46	2.41	2.75	2.48	2.34
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	2.23	2.53	2.42	2.39	2.37	2.65	2.44	2.30
T_{12} FYM only @ 10 t/ha	2.19	2.42	2.35	2.32	2.30	2.58	2.37	2.25
SEm ±	0.065	0.068	0.044	0.055	0.058	0.051	0.041	0.061
CD @ 0.05	0.19	0.20	0.13	0.16	0.17	0.15	0.12	0.18
CV (%)	11.95	10.48	9.29	10.32	8.13	7.69	8.94	7.84

Table 7: Effect of long-term use of inorganic fertilizers, organic manures and their combination on available soil copper (mg kg^{-1})

Treatments	*Kharif* (2016)				*Rabi* (2017)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	0.52	0.51	0.50	0.50	0.49	0.49	0.48	0.46
T_2 100% RDF	1.72	1.92	1.84	1.76	1.77	1.97	1.93	1.81
T_3 100% NK	1.63	1.74	1.63	1.67	1.65	1.88	1.82	1.69
T_4 100% PK	1.61	1.73	1.62	1.70	1.68	1.91	1.87	1.72
T_5 100% NP	1.62	1.79	1.68	1.65	1.64	1.98	1.80	1.68
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	1.73	1.92	1.87	1.79	1.78	2.02	1.95	1.81
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1.94	3.24	2.16	1.96	1.95	3.35	2.25	1.99
T_8 50% NPK	1.56	1.69	1.64	1.60	1.58	1.61	1.68	1.62
T_9 50% NPK + 50% N Through Green Manures	1.71	2.81	1.93	1.74	1.72	3.01	2.02	1.78
T_{10} 50% NPK + 50% N Through FYM	1.81	3.11	1.97	1.84	1.86	3.26	2.13	1.90
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	1.75	2.86	2.08	1.78	1.76	3.10	1.97	1.79
T_{12} FYM only @ 10 t/ha	1.83	3.19	2.11	1.87	1.84	3.22	2.18	1.88
SEm ±	0.038	0.056	0.051	0.044	0.031	0.058	0.048	0.058
CD @ 0.05	0.11	0.17	0.15	0.13	0.09	0.15	0.14	0.17
CV (%)	8.71	8.56	7.39	8.21	11.43	9.52	7.41	8.92

Table 8: Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil available copper (mg kg^{-1})

Treatments	*Kharif* (2017)				*Rabi* (2018)			
	Initial	Tillering	Panicle Initiation	Harvest	Initial	Tillering	Panicle Initiation	Harvest
T_1 Control	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.39
T_2 100% RDF	1.76	1.99	1.91	1.79	1.71	1.99	1.96	1.81
T_3 100% NK	1.67	1.70	1.79	1.69	1.64	1.87	1.85	1.74
T_4 100% PK	1.71	1.79	1.75	1.73	1.69	1.91	1.89	1.72
T_5 100% NP	1.65	1.92	1.84	1.69	1.62	1.79	1.75	1.73
T_6 100% RDF + $ZnSO_4$ @ 40 kg/ha	1.79	1.99	1.98	1.80	1.73	2.01	1.99	1.89
T_7 100% RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1.99	3.32	2.29	2.04	2.01	3.49	2.31	2.13
T_8 50% NPK	1.60	1.75	1.71	1.62	1.53	1.77	1.72	1.64
T_9 50% NPK + 50% N Through Green Manures	1.77	3.01	2.01	1.84	1.75	3.09	2.19	1.87
T_{10} 50% NPK + 50% N Through FYM	1.89	3.19	2.15	1.91	1.86	3.32	2.27	1.92
T_{11} 50% NPK + 25% N Through GM + 25% N Through FYM	1.75	3.04	2.08	1.81	1.79	3.16	2.01	1.83
T_{12} FYM only @ 10 t/ha	1.86	3.26	2.21	1.89	1.80	3.29	2.25	1.91
SEm ±	0.044	0.063	0.061	0.055	0.065	0.069	0.044	0.041
CD @ 0.05	0.13	0.19	0.18	0.16	0.19	0.21	0.13	0.12
CV (%)	9.63	9.42	7.94	8.45	7.84	8.65	8.56	9.16

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