Original Research Article

Long term effect of different nutrient management practices on micro nutrient uptake under rice-rice cropping system

ABSTRACT

A field experiment entitled "Long term effect of different nutrient management practices on micro nutrient uptake under rice-rice cropping system" was conducted 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 findings demonstrate that the data regarding influence of long-term use of inorganics, organics and their combination on micronutrient uptake at different growth stages in *kharif* and *rabi* during both the years of the study revealed that there was increase significantly with application of 100% RDF in combination with $ZnSO_4$ and FYM @ 5t ha^{-1}. 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. Application of 100 % RDF along with $ZnSO_4$ @ 40 kg ha^{-1} and application of 100 % NPK though not differ significantly and on par with each other during four seasons of study.

Key words: Bio-fertilizers; micronutrients; organic manure; Zn uptake.

INTRODUCTION

"India ranks second in rice production with 110.9 million tonnes and productivity 2.28 t ha^{-1} from an area of 39.47 million hectares. In Andhra Pradesh, rice is grown in an area of 23.30 lakh ha with annual production of 104.88 lakh tones and productivity of 2,820 kg ha^{-1}" (Indiastat, 2015-16). "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). "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). 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.

A large number of experiments (Sharma *et al.*, 2008) at research stations and on farmers field have demonstrated the importance of organic manures, farmyard manure and bio - fertilizers supplementing the nutrient requirements of crop and providing yield stability. Farming systems and the best management practices that hold promise for sequestering soil organic carbon, potential to enhance agricultural sustenance, reduce negative environment impacts of anthropogenic CO_2 emissions need to be identified and thoroughly investigated.

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 current 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 experiment was located at 81^0 44' E to 81^0 73' E longitude and 16^0 37' N to 16^0 62' N latitude and 5 m above mean sea level. The weekly mean maximum temperature ranged from 28.3°C to 35.1°C and 21.14°C to 32.57°C during 2016 and 2017, respectively. The mean minimum temperature for the corresponding period ranged from 19.0°C to 28.6°C and 18.0°C to 27.7°C respectively, while the mean maximum and minimum temperatures during the same period were 31.78 °C and 23.99 °C during 2016, and 30.02°C and 25.04°C during 2017, respectively. The weekly mean relative humidity ranged from75.8 % to 84.0% during 2016 and 81.14% to 90.42 % during 2017, while the mean relative humidity was 79.61 % and86.10%, during 2016 and 2017. A total rainfall of 720.2 mm and 777.8 mm was received during 2016 and 2017, respectively. "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 ($1/3^{rd}$ 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" [Goutami et al. 2018]. 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 g ha^{-1}.

$$\text{Macronutrient Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Drymatter yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Micronutrient Uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{1000}$$

RESULTS AND DISCUSSION

Iron uptake

The iron uptake data at tillering, panicle initiation and at harvest stage were statistically computed 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 highest iron accumulation in grain was observed in T_7 (100% RDF+$ZnSO_4$+FYM @ 5 t ha^{-1}) which was significantly superior over all other treatments in *kharif*, *rabi* during both the years of study. As expected, untreated control (T_1) registered the lowest iron uptake (0.37, 0.48, 0.37, 0.48 kg ha^{-1} in *kharif*, *rabi*, 2016-17 and 2017-18, respectively. The lowest K uptake in control plot by the crops is due to the lower yield obtained in these plots.

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 K uptake was observed in 100% RDF + FYM + $ZnSO_4$ with 3.29, 4.15, 3.41, 4.21 kg 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.

Among the inorganic treatments (T_2, T_3, T_4, T_5 T_6 and T_8), the highest iron 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. The treatments T_3, T_5 were on par with each other and significantly superior over T_4 and T_8. Similar results were obtained in all the crop growth stages during both the years of study in *kharif* and *rabi*.

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). N application might have enhanced the uptake of iron by changing rhizosphere pH. Similar results were reported by Singh *et al.* (1995) and Behara (2004).

Manganese uptake

Data on Mn uptake by rice at different growth stages in various treatments are presented in table (5 & 6) Showed that significant variations on Mn uptake during both the years of study.

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 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. The earlier reports of Latha *et al.* (2002) supported the present findings.

Zinc uptake

Data pertaining to effect of organics, inorganics and their combination on Zn uptake by rice at different stages presented in table 1 and 2 revealed 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 kg 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 kg 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 enhancement of Zn content and its uptake due to FYM reported by Datta and Singh (2010).

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 kg 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) 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".

Among the combined treatments (T_7, T_9 ,T_{10} and T_{11}), the treatment which received 100% RDF+ $ZnSO_4$ + FYM @ 10 t ha^{-1} (T_7) had maximum zinc uptake in rice grain with 180.19, 263.79, 199.32, 283.89 kg ha^{-1} , respectively in *kharif*, *rabi* during both the years of study and it was significantly superior over T_9, T_{10} and T_{11} and the lowest (46.08, 62.51, 44.95, 61.62 kg ha^{-1}, respectively in two years of study) zinc uptake was observed in control (T_1). Among the inorganic treatments of NPK (T_2, T_3, T_4, T_5 and T_8), the zinc uptake with 100% RDF (T_2) was highest which was significantly superior to T_3 (100% NK), T_4 (100 % PK), T_5 (100 % NP) and T_8 (50 % NPK). However, the treatments T_4, T_5 and T_8 were on par with each other.

Application of organics proved to increase the Zn uptake significantly by rice straw and grain as against the application of RDF alone (M_1). "Application of organics increased the Zn uptake which might be due to greater availability of micronutrients in the soil as well as the organics. In majority of studies, there was a significant positive relationship between organic matter and available Zn in soils" as also reported by (De *et al.*, 1994).

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 kg 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.

Higher uptake of nutrients in the treatments involving addition of FYM or GM along with fertilizers might be attributed to the extra amount of nutrients supplied by the FYM and GM, which influenced to increase the yield and ultimately showed higher uptake of nutrients. This was in agreement with the findings of Kumar and Yadav (1993).

Copper uptake

Results of the present investigation shown in reported that the copper uptake was significantly influenced by different treatments.

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. These results were in line with the findings of Tyagi and Bhardwaj (1994) who revealed that FYM treated plots recorded the highest uptake of all the nutrients, indicating that the addition of FYM along with 100% NPK increased the uptake of nutrients to a greater extent in rice-wheat rotation. 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.

These results were in conformity with the findings of Ghosh *et al.* (2001) who reported that application of FYM along with recommended dose of NPK fertilizer considerably increased the uptake of Cu by rice over RDF treatment.

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_7 which 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 % N through 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}. The lowest in control (T_1) which was significantly different from all the treatments. 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.

Among the inorganic treatments (T_2, T_3, T_4, T_5, T_6 and T_8), the copper uptake with 100% RDF+ $ZnSO_4$ (T_6) was highest and it was significantly superior over T_3, T_4, T_5 and T_8 but

however it was on par with T_2. Similar results were observed in both the years of study in *kharif* and *rabi* in all the growth stages.

Das and Mandal (1986) reported that "the uptake of Cu by the rice, straw and grain was found to be more in the rice plants grown under waterlogged condition. The higher Cu uptake by the different plant parts of rice under waterlogged condition could be explained due to favourable chemical environment of the root medium leading to higher root proliferation and nutrient absorption by the rice under reducing conditions".

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.

CONCLUSIONS:

Based on the findings of this study, it is concluded that Data on the uptake of all micronutrients by the rice crop were higher with the application of 100% RDF combined with $ZnSO_4$ and FYM @ 5t ha-1 and it was significantly better than other treatments, but it was comparable to that of application of 100% RDF combined with $ZnSO_4$ @ 40 kg ha-1 during both the study years in kharif and rabi. The application of 50 % NPK + 50 % N through FYM was on par with 100 % RDF. The treatments had a significant impact on the uptake of all the macronutrients, and the application of 100% RDF along with $ZnSO_4$ and FYM at 5t ha-1 produced better results than other treatments.

FUTURE SCOPE OF STUDY:

The continuous rice cultivation with traditional method imposed serious threats to natural resources and agricultural sustainability. In the scenario of declining factor productivity, crop response and water table and rising air pollution, researchers and policymakers need to intervene through a systematic and integrated approach to produce more rice with less water in a sustainable way.

References:

Behara, S.K. 2004. Nutrient response of uptake of N, P and K by rice under long term fertilizer use on mollisol. *Oryza.* 41 (3&4): (133-134).

Das, D. K and Mandal, L. N. 1986. In: Micronutrients: Their Behaviour in Soils and Plants (D. K. Das, ed.), pp. 47 – 126, Kalyani Publishers, New Delhi-110002.

Datta, M and Singh, N.P. 2010. Nutrient management in rice based cropping systems asinfluenced by applying cattle manure alone or in combination with fertilizers inupland acid soils of Tripura. *Journal of the Indian Society of Soil Science.* 58(1):94-98.

De, B., De, S. K and Das, D. K. (1994). *Indian Agriculture*. 38: 201 – 205.

Ghosh, B.N., Prakash, V and Singh, R.D. 2001. Micronutrient status in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system in kumaon region of Uttaranchal. *Indian Journal of Agricultural Sciences*. 71 (2): 149-152.

Gurra, L.C., Bhuinya, S.I., Toung, T.P and Barker, R. 1998. Producing more rice with less water, *International Water Management Institute,SWIM*. Paper, 5: 24-28.

Kumar, A and Yadav, D.S. 1993. Effect of long-term fertilization on soil fertility and yield under rice-wheat cropping system. *Journal of the Indian Society of Soil Science*. 41: 178-180.

Latha, M.R., Savithri, P., Indrani, R and Kamraj, S. 2002. Residual effect of zinc enriched organic manures on yield and zinc uptake in sunflower under maize sunflower cropping sequence. *Agriculture Science Digest*. 2(22): 114-116.

Prasad, B and Umar, S. M. 1993. Direct and residual effect of soil application of zinc sulfate on yield and zinc uptake in a rice-wheat rotation. *Journal of Indian Society of Soil Science*. 41(1): 192-194.

Shanmugam, P.M and Veeraputhran, R. 2001. Effect of organic and inorganic N and zinc application on soil fertility and nutrient uptake of rabi rice (*Oryza sativa*). *Madras Agricultural Journal*. 87 (1-3): 90-92.

Sharma, K.L., Kusuma Grace, J., Mandal, U.K., Gajbhiye, P.N., Srinivas, K., Korwar, G.R, Bindu, V.H., Ramesh,V., Ram chandran , K and Yadav, S.K. (2008). Evaluation of long

term soil management practices using key indicators and soil quality indices in a semi and tropical Alfisol. *Australian Journal of Soil research*. 46: 368-377.

Sharma, R.A and Dixit, B.K. 1987. Effect of nutrient application on rainfed soybean. *Journal of Indian Society of Soil Science.* 35: 452-455.

Singh, A., Awasthi, R.P., Singh, R.D and Arya, R.L. 1995. Effect of inorganic fertilizers in maize (*Zea mays*) + ginger (*Zingiber officinale*) intercropping system in humid hilly soils. *Indian Journal of Agronomy*. 40(4): 549-552.

Sriram Chandrasekharan, M.V. 2001. Effect of organic manures on the nutrient uptake, yield and nutrient use efficiency in lowland rice. *Journal of Ecobiology*. 13(2): 143-147.

N Goutami, Ch Sujani Rao, A Sireesha, Ch Pulla Rao and A Vijaya Gopal. Long term effect of integrated nutrient management on macro nutrient uptake under rice-rice sequence. International Journal of Chemical Studies 2018; 6(6): 1239-1244

Table 1. 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 2. 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 3. 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

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Table 4. 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 5. 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 6. 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 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

Fig – 1 A general view of field experiment in clay loam soil during *rabi*, 2017