

**FOLIAR APPLICATION OF IRON AND ZINC ON GROWTH, YIELD  
AND NUTRIENT UPTAKE OF PADDY**

by

**Miss. Dhindale Madhuri Suresh.**

**(Reg. No. K- 15/109)**

A Thesis submitted to the  
**MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI- 413 722, DIST- AHMEDNAGAR,  
MAHARASHTRA, INDIA.**

In partial fulfillment of the requirements for the degree  
of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

**DIPARTMENT OF SOIL SCIENCE AND AGRICULTURAL  
CHEMISTRY,**

**COLLEGE OF AGRICULTURE, KOLHAPUR - 416 004**

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**RAHURI -413722, DIST-AHMEDNAGAR**

**2017**

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**2017**

## CANDIDATE'S DECLARATION

I hereby declare that this thesis or part  
there of has not been submitted  
by me or other person to any  
other University or Institute  
for a Degree or  
Diploma

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## C E R T I F I C A T E

This is to certify that, the thesis entitled “**FOLIAR APPLICATION OF IRON AND ZINC ON GROWTH, YIELD AND NUTRIENT UPTAKE OF PADDY**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirement for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**, is a record of bonafide research work carried out by **Miss. Dhindale Madhuri Suresh** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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*Place : A. C. Kolhapur*

*Date :     /     /2017*

*(Miss. Dhindale. M. S.)*

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## LIST OF ABBREVIATIONS

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%	: Per cent
@	: At the rate of
Agric.	: Agriculture
Agron.	: Agronomy
Am.	: American
Anal.	: Analysis
B	: Boron
Biol.	: Biology
C.D.	: critical difference
Ca	: Calcium
CaCO <sub>3</sub>	: Calcium carbonate
Chem.	: Chemistry
cm	: Centimeter (s)
CRD	: Completely Randomized Block Design
Cu	: Copper
DAS	: Days after sowing
DTPA	: Diethylene triamine penta acetic acid
EC	: Electrical conductivity
<i>et al.</i>	: et alli (and others)
Ecol.	: Ecology
Environ.	: Environment
Fe	: Iron
Fe-EDTA	: Iron- Ethylene Di amine Tetra Acetic Acid
FeSO <sub>4</sub>	: Ferrous Sulphate

Fig.	: Figure
FYM	: Farm Yard Manure
Fertil.	: Fertilizer
g	: gram
GMs	: Green manures
GRDF	: General recommend dose of fertilizers
$g\ m^{-2}$	: gram per meter square
ha.	: Hectare
i.e.	: id est (that is)
Int.	: International
J.	: Journal
K	: Potassium
$K_2O$	: Potash (potassium oxide)
kg	: Kilogram (s)
$kg\ ha^{-1}$	: kilogram per hectare
LAI	: Leaf area index
Ltd.	: Limited
m	: meter
<i>M</i>	: Molar
Mg	: Magnesium
Mn	: Manganese
$m^2$	: meter square
$mg\ kg^{-1}$	: milligram per kilogram
$mg\ pot^{-1}$	: milligram per pot
MT	: million tons
N	: Nitrogen

<i>N</i>	: Normal
N.S.	: Non-significant
NaSe	: Sodium Selenite
No.	: Number
P	: Phosphorus
Pl.	: Plant
P <sub>2</sub> O <sub>5</sub>	: Phosphorus penta oxide
pH	: Soil reaction
ppm	: Parts per million
Pvt.	: Private
Res.	: Research
S	: Sulphur
Sci.	: Science
S.E. ±	: Standard error
Soc.	: Society
t	: ton (s)
t ha <sup>-1</sup>	: ton per hectare
Univ.	: University
U. P.	: Uttar Pradesh
Vol.	: Volume
ZEU	: Zinc enriched urea
Zn	: Zinc
Zn-EDTA	: Zinc- Ethylene Di amine Tetra Acetic Acid
ZnO	: Zinc oxide
ZnSO <sub>4</sub>	: Zinc Sulphate
ZnSHH	: Zinc sulphate hepta hydrate

**ABSTRACT**

.....  
**“Foliar application of iron and zinc on growth, yield and  
nutrient uptake of paddy”**

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COLLEGE OF AGRICULTURE, KOLHAPUR

MAHARASHTRA (INDIA)

**2017**

.....  
**Research Guide : Dr. B. S. Kadam**

**Department : Soil Science and Agricultural  
Chemistry**

.....  
An experiment entitled, “Foliar application of iron and zinc on growth, yield and nutrient uptake of paddy” was conducted during *kharif* season of 2016-2017 in wire house of division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur. The objectives of experiment were to study the effect of iron and zinc on growth, yield and nutrient uptake of paddy and on chemical properties of soil at harvest. The present investigation was carried out in Completely Randomized Block Design. Treatments comprised of two levels with two sources of each iron and zinc. The sources of iron as FeSO<sub>4</sub>, Fe-EDTA and for zinc as ZnSO<sub>4</sub>, Zn-EDTA which are

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**Abstract contd.....**

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 replicated thrice along with fourteen treatments.

Plant height and number of tillers increased significantly over control due to foliar application of Fe and Zn. The highest plant height (63.59 cm) and highest no. of tillers (25.66 pot<sup>-1</sup>) were recorded by foliar application of Fe-EDTA and Zn-EDTA each @ 0.5 % with GRDF.

The treatment T8 (Fe-EDTA and Zn-EDTA each @ 0.5 % foliar application with GRDF) recorded significantly superior grain and straw yield (35.54 and 39.01 g pot<sup>-1</sup> respectively) of paddy over all the treatments.

The N, P, K uptake was significantly increased due to foliar application of different sources with concentrations of Fe and Zn. The treatment T8 (Fe-EDTA and Zn-EDTA each @ 0.5 % foliar application with GRDF) recorded significantly highest uptake of N, P, K (588.50, 164.10 and 712.57 mg pot<sup>-1</sup> respectively) by paddy.

The micronutrients Fe, Mn, Zn, Cu uptake (0.496, 0.013, 0.010 and 0.011 mg pot<sup>-1</sup>) was significantly increased due to foliar application of different sources and concentrations of Fe and Zn with GRDF.

After harvesting the crop, no significant changes were recorded in chemical properties of soil (pH, EC, organic carbon, calcium carbonate, available N, P, K and micronutrients) due to application of foliar spray of Fe and Zn with GRDF.

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**Abstract contd.....**

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The results of present investigation showed that foliar application of Fe-EDTA + Zn-EDTA @ 0.5 % each with GRDF significantly increased the growth, yield, and total nutrient uptake (N, P and K) and micronutrients (Fe and Zn) of paddy.

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**Page 1 to 62**  
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## 1. INTRODUCTION

Rice is the principal staple food crop of the world. It plays a vital role in our national food security and is means of livelihood for millions of households. Rice contributes more than 40 per cent of total food grain production. India is the largest producer of rice as 105 MT from 43.5 million hectares with average productivity 2.2 t ha<sup>-1</sup> next to the China. In Maharashtra it is 26.87 lakh ton from 15.18 lakh ha with average productivity 1.77 t ha<sup>-1</sup> and in Kolhapur it is 6.08 lakh ton from 3.29 lakh ha with average productivity 1.85 t ha<sup>-1</sup> (Anonymous, 2016).

There are various factors which influence the production of rice like incidence of pest and diseases, water managements, low soil fertility and fertilizer use efficiency, poor agronomic practices. In that nutrient availability as macro and micro nutrients is also a major factor which influence the production of rice. Certain soil conditions induce micronutrient deficiency to a growing crop as soils with very high pH, light textured soils with low pH, soils developed under very high rainfall. In acid sulphate soils, micronutrient toxicity limits the crop growth under upland soil conditions. Iron toxicity in rice is observed in soils rich in Fe, under highly reducing submerged soil conditions due to the presence of easily decomposable organic matter.

The micronutrients are present in soils mainly as their oxides, sulphides and silicates and are inherited from the soil-forming rocks and minerals through transformation during

various stages of soil development. The parent material from which the soil developed and soil forming processes determines what the micronutrient content of the soil will be. As minerals break down during soil formation, micronutrients are gradually released in a form that is available to plants. Two sources of readily available micronutrients exist in soil: nutrients that are adsorbed onto soil colloids and nutrients that are in the form of salts dissolved in the soil solution. The natural sources of zinc are Sphalerite (ZnS), Smithonite ( $\text{ZnCO}_3$ ), Hemimorphite [ $\text{Zn}_4(\text{OH})_2\text{SiO}_7 \cdot \text{H}_2\text{O}$ ] and sources for iron are Hematite ( $\text{Fe}_2\text{O}_3$ ), Goethite ( $\text{FeOOH}$ ), Magnetite ( $\text{Fe}_3\text{O}_4$ ), Pyrite ( $\text{FeS}_2$ ), Olivine [ $(\text{Mg}, \text{Fe})_2\text{SiO}_4$ ].

Micronutrients play an important role in rice cultivation. Micronutrient does not mean that they are less important to plants than other nutrients. Plant growth and development may be retarded if any of these elements is lacking in the soil or is not adequately balanced with other nutrients. Micronutrient deficiencies are widespread, 50% of world cereal soils are deficient in zinc and 30% of cultivated soils globally are deficient in iron. Steady growth of crop yields during recent decades (in particular through the green revolution) compounded the problem by progressively depleting soil micronutrient pools. In general, farmers only apply micronutrients when crops show deficiency symptoms, while micronutrient deficiencies decrease yields before symptoms appear.

Zinc is the most common micronutrient disorders in wet-land rice (often combined with P deficiency). Due to increase

availability of Ca , Mg , Cu , Fe , Mn and P under prolonged submergence Zn availability and uptake hampered by the crops. Zinc is essential for several biochemical processes such as cytochrome and nucleotide synthesis, enzyme activation, chlorophyll production, maintenance of membrane activity, increase rate of seed and stalk maturation. Deficiency symptoms cause brown to dusty brown spots on younger leaves (2-4 weeks after transplanting) in red soils, yellowing of leaves/midrib bleaching. Zinc deficiency in rice soil is commonly known as *khaira*. The main symptom of *khaira* in rice is usually in nursery; chlorotic/yellow patches at leaf base on both sides of the midrib; restricted root growth and usually main roots turn brown.

Iron deficiency is common in upland, high pH and aerobic soil. Iron helps in the formation of chlorophyll. A deficiency of iron causes interveinal yellowing and chlorosis of emerging leaves, less dry matter production, reduced sugar metabolism enzymes, plant become stunted with narrow leaves.

Various agronomic approaches can be used to correct micronutrient disorders. Once a deficiency is reliably identified, it can generally be corrected by chemical amendments that suit the plant demand and farmer options. The amount, form, mode and timing are critical, especially if multiple nutrient stresses and antagonisms among nutrients are present.

Though the iron and zinc deficiency is difficult and costly micronutrient deficiency to correct, it can be corrected by soil

or foliar application of source of iron and zinc micronutrient respectively. In view of this the present investigation is aimed to evaluate the effect of zinc and iron on growth, yield and nutrient uptake by paddy in iron and zinc deficit soil with following objectives.

1. To study the effect of iron and zinc on growth and yield of paddy.
2. To study the effect of iron and zinc on nutrient uptake by paddy.
3. To study the effect of iron and zinc on chemical properties of soil at harvest.

## **2. REVIEW OF LITERATURE**

This chapter deals with the review of research work carried out by various researches on effect of foliar application of iron and zinc on paddy with following headings.

**2.1** Effect of iron and zinc on growth of paddy

**2.2** Effect of iron and zinc on yield of paddy

**2.3** Effect of iron and zinc on nutrient uptake by paddy

**2.4** Effect of iron and zinc on chemical properties at harvest

### **2.1 Effect of iron and zinc on growth of paddy**

#### **2.1.1 Plant height (cm)**

Kulandaivel *et al.* (2004) observed that the levels and mode of application of iron considerably increased the growth, yield attributes and yield of rice-wheat cropping system.

Ghatak *et al.* (2005) reported that the increase plant height with increasing levels of Zn.

Sarangi *et al.* (2006) observed that Fe as foliar through Fe-EDTA recorded relatively larger plant height (cm) over Fe as soil through Fe-EDTA at all the stages of plant growth, probably due to higher Fe uptake through aerial portion of plant under foliar spray.

Mandal *et al.* (2009) reported that the effect of levels of Zn in respect of FYM and recommended dose of NPK significantly influenced all the growth attributes of rice. The application of Zn in split doses proved to be significantly superior than the application of same amount of Zn as basal

which might be due to split application increased the Zn use efficiency. Plant height as well as volume of roots increased with increasing the levels of Zn from 5 kg ha<sup>-1</sup> to 10 kg ha<sup>-1</sup> might be due to greater availability of Zn to the plants.

Yadav (2012) reported that levels and methods of FeSO<sub>4</sub> significantly influenced the plant height of aerobically grown rice. The application of FeSO<sub>4</sub> @ 100 kg ha<sup>-1</sup> recorded significantly higher plant height over control at 60 DAS. Similar to plant height, application of FeSO<sub>4</sub> @ 100 kg ha<sup>-1</sup> recorded significantly higher LAI at 30 DAS.

Saha *et al.* (2013) observed that Zn application through both soil and soil plus foliar applications resulted a significant increase in plant height over control. The magnitude of such increase was higher with soil plus foliar application of Zn than only soil application irrespective of the cultivars tested. Among the rice cultivars, the highest value (203.1 cm) was recorded in Kalma 222, a local cultivar and the lowest (92.9 cm) was in IR 64, a high yielding cultivar.

Ram *et al.* (2013) observed that among the different micronutrient treatments, soil application of Zn-EDTA @ 1.00 kg ha<sup>-1</sup> followed by foliar spray of Fe-EDTA @ 0.5 kg ha<sup>-1</sup> recorded significantly higher plant height (110.55 cm) as compared to other micronutrient treatments.

Das (2014) Stated that micronutrients refers to the relative quantity of a nutrient that is required for plant growth. It takes part in metabolic activities, enzymatic process/catalysts etc. Thus these all directly and indirectly help in plant growth and development.

Shivay *et al.* (2015) observed that three foliar applications of Zn-EDTA (at tillering, booting, and grain filling stages) @ 0.5 % was the best treatment and recorded significantly higher growth of Basmati rice (var. Pusa Sugandha 5) than soil application of ZnSHH or Zn-EDTA and two or a single foliar application of ZnSHH or Zn-EDTA.

### **2.1.2 Number of Tillers**

Rakesh *et al.* (2012) conducted a field experiment at Agricultural Research Station, Kampasagar, Nalgonda district of Andhra Pradesh to find the response of aerobic rice to varying fertility levels in relation to iron application. They found that tillers  $m^{-2}$  and plant dry matter  $g m^{-2}$  at various stages (active tillering, panicle initiation, flowering and at harvest) increased from the treatment  $N_{180}P_{60}K_{40}$  (no iron application) to  $N_{180}P_{60}K_{40}FeSO_{425}$  but the results were found non-significant.

Saha *et al.* (2013) observed that higher number of tillers per hill from Zn treated plots compared to untreated control irrespective of the rice cultivars. On an average, number of tillers per hill of the tested cultivars varied from 9.7 to 22.8 with a mean value of 15.00. The highest number of tillers per hill (22.8) was recorded in the cv. Satabdi, a high yielding cultivar with basal application of Zn fertilizers but the lowest number (9.7) was recorded in the cultivar IR 64, a high yielding cultivar in untreated control. On an average, 17% increase in the number of tillers per hill was found with basal application of Zn over control.

Radhika *et al.* (2013) observed that among the different concentration of kiecite evaluated, application of 1.0 % level has significantly increased the number of tillers.

Ram *et al.* (2013) observed that among the different micronutrient treatments, soil application of Zn-EDTA @ 1.00 kg ha<sup>-1</sup> followed by foliar spray of Fe-EDTA @ 0.5 kg ha<sup>-1</sup> recorded significantly higher number of tiller m<sup>-2</sup> (445.95 m<sup>-2</sup>) as compared to other micronutrient treatments.

Suresh and Salakinkop (2016) observed that combined soil application of ZnSO<sub>4</sub> and FeSO<sub>4</sub> each @ 25 kg ha<sup>-1</sup> and foliar spray of ZnSO<sub>4</sub> and FeSO<sub>4</sub> each @ 0.5 % recorded significantly higher number of tillers per meter row length.

## **2.2 Effect of iron and zinc on yield of paddy**

Takaki and Kushizaki (1970) reported that participation of Zn in biosynthesis of indole acetic acid (IAA) and its role in initiation of primordial reproductive parts and partitioning of photosynthates towards them are responsible for increased yield.

Panda and Nayak (1974) reported that application of zinc increased significantly the number of effective tillers m<sup>-2</sup>, plant height, number of grains panicle<sup>-1</sup> and 1000 grain weight on both 'Jaya' and 'Ratna' varieties of rice of different locations.

Dargan *et al.* (1976) conducted field trials on maize, berseem and rice grown on highly sodic soil and reported that application of sulphur as gypsum with zinc as zinc sulphate (45 kg ha<sup>-1</sup>) increased the yield of crops.

Gill and Singh (1978) stated that the application of  $\text{ZnSO}_4$  @ 20 kg ha<sup>-1</sup> increased significantly the productive tillers, panicle length, number of grains panicle<sup>-1</sup> and grain yield in rice.

Agarwala *et al.* (1980) conducted 18 field trials at 15 locations in U.P. on wheat rice and maize grown having less than 0.39 ppm Zn in non-calcareous soils and less than 0.74 ppm in alkaline soils. Zinc application increased significantly the grain yield of rice, wheat and maize.

Balakrishnan and Natarajaratnam (1986) stated that NPK and Zn give the highest paddy yield with 25 kg  $\text{ZnSO}_4$  ha<sup>-1</sup>. Applied Zn increased the number of tillers plant<sup>-1</sup>, panicle length, number of total grains and filled grains panicle<sup>-1</sup> and test weight.

Babiker (1986) reported that zinc sulphate fertilizer application @ 0, 25, 50, and 75 kg ha<sup>-1</sup> in nursery and field experiments on rice increased leaf area index, plant height, productive tillers, panicle length, number of filled and unfilled grains per panicle, 1000 grain weight (test weight) and yield.

Vyas *et al.* (1990) conducted a field trail in the Kharif (Monsoon) season of 1985 on a clay soil at Raipur, Madhya Pradesh, rice cv. Samradhi was given 0-20 kg Zn ha<sup>-1</sup>. Grain yield and total N uptake were highest with 5 kg Zn ha<sup>-1</sup> (3.75 t ha<sup>-1</sup> and 74.64 kg ha<sup>-1</sup>, respectively).

Sahay *et al.* (1992) assessed the response to Zn and B in paddy and wheat under different soil agro-climatic conditions of Bihar during 1987-90, 30 field trials on paddy and 26 on

wheat with 4 levels of zinc sulphate were conducted in districts of Madhubani, Munger, Saran, and Siwan with the recommended rate of NPK. The range of yield response to 25 kg ha<sup>-1</sup> zinc sulphate in paddy was from 1.093 to 1.111 t ha<sup>-1</sup> and in wheat from 0.585 to 0.835 t ha<sup>-1</sup>.

Singh and Sharma (1994) observed that 20 kg ZnSO<sub>4</sub>, 0.5 kg chelated Zn or 0.5 kg Zn-EDTA ha<sup>-1</sup> as a basal application, top dressing or in 3 foliar sprays of 0.5%, 0.1% and 0.01% for the 3 sources, respectively to rice cv. Sarju-52. Grain yield was highest with a basal dose of 20 kg ZnSO<sub>4</sub> ha<sup>-1</sup> as a top dressing or 3 foliar sprays gave the lowest grain yield.

Tomar *et al.* (1994) conducted a field experiment to study the response of high yielding rice cv. IR-28 and Kiran to 0-100 kg ZnSO<sub>4</sub> ha<sup>-1</sup>. Application of 50 and 75 kg ZnSO<sub>4</sub> ha<sup>-1</sup> increased grain yield significantly, the yield response was greater in Kiran. Additional yield of 1.10 t ha<sup>-1</sup> was obtained with 75 kg ZnSO<sub>4</sub> ha<sup>-1</sup> over no Zn.

Nandram (1996) reported that the addition of Zn and FYM along with 100% NPK enhanced the mean grain yield of rice by 12% and 14%, respectively, compared with 100% NPK alone. A Zn deficiency disease in rice known as *khaira*, was prevalent in the control and 100% NPK treatment, but disappeared after the addition of either Zn or FYM.

Channal and Kandaswamy (1997) reported that the application of 37.5 kg ZnSO<sub>4</sub> and gypsum + dhaincha produced the highest rice yield of 5.63 t ha<sup>-1</sup>.

Alam *et al.* (1998) studied the effect of zinc application with or without copper on yield and composition of rice genotype Basmati-385 and a mutant DM-25 in a pot culture experiment. Rice genotypes responded to Zn application much more in presence of Cu than its application alone. The Zn  $\times$  Cu interaction significantly increased grain and straw yield and total Zn uptake by both rice genotypes. However, Basmati-385 compared to the mutant DM-25 gave higher response to Zn in the presence of Cu. Higher Zn and Cu uptake by Basmati-385 was attributed to its higher straw yield rather than its differential concentration in grain and straw.

Panda and Sahu (1999) grown rice cv. Kalinga 90 in pots at soil zinc levels of 50, 200 or 400 mg kg<sup>-1</sup> and found contents of chlorophyll a and b, carotenoid, sugars, amino acids and protein and yields and biomass production increased with 50 mg Zn compared with the control, but decreased at higher concentrations.

Channabasavanna and Biradar (2001) reported that the application of poultry manure with 25 kg ZnSO<sub>4</sub> ha<sup>-1</sup> recorded significantly higher yields over the rest of the treatments. The increase in yield was attributed to panicles per hill and seeds per panicle. The residual effect was attributed to panicles per hill and seeds per panicle. The residual effect was prominent when rice husk was applied. Pressmud did not respond to applied ZnSO<sub>4</sub> while crop responded to zinc up to 50 kg ha<sup>-1</sup> when no organic manure was applied.

Mian *et al.* (2001) reported that deficiencies in soil zinc (Zn) may limit yield of rice and wheat in rice tract of Punjab

(Gujranwala and Lahore Divisions). The build up of phosphorus (P) due to its continuous application could also reduce the plant Zn concentrations. There were two levels of P (100 and 200 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) and three levels of Zn i.e. 0, 3.5 and 7 for wheat and 0, 5 and 10 kg ha<sup>-1</sup> for rice. Wheat yield data revealed that Zn addition at the rate of 3.5 kg ha<sup>-1</sup> improved the grain yield significantly while there was no difference in the yield in treatments, receiving 100 and 200 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>. A reverse situation was attained in rice where high P (200 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) did increase the paddy yield significantly while Zn at the rate of 5-10 kg ha<sup>-1</sup> was not successful to enhance the yield. The reason was satisfactory levels of soil Zn built up to 1.6-2.8 mg ka<sup>-1</sup> soil due to residual effect of Zn applied to previous crop i.e. wheat.

Kumar *et al.* (2002) reported that among the various sources of zinc, chelated zinc resulted in the highest grain (2.923 t ha<sup>-1</sup>) and straw (4.861 t ha<sup>-1</sup>) yield; nitrogen (1.16%), phosphorus (0.28%), potassium (0.47%) and zinc (2.201%) contents of grain; and nitrogen (0.52%), phosphorus (0.096%), potassium (0.54%) and zinc (5.188%), contents of straw. The application of zinc and phosphorus significantly increased yield and nutrient uptake. Among the zinc rates, 10 ppm gave the highest grain (3.000 t ha<sup>-1</sup>) and straw (4.825 t ha<sup>-1</sup>) yields.

Muhammad *et al.* (2002) reported that the number of tillers pot<sup>-1</sup>, number of grains panicle<sup>-1</sup>, 1000 grain weight and grain yield increased significantly with the application of Zn, Fe and Mn alone or in various combinations. However, additional increase in rice yield and yield contributing growth

parameters was noted in treatment comprising 10 mg Zn kg<sup>-1</sup> along with 5 mg Mn kg<sup>-1</sup> and a basal dose of N, P and K fertilizers.

Jadhav *et al.* (2003) studied the effects of Zn fertilizers with or without FYM on the performance of rice cv. Ratnagiri in Konkan, Maharashtra. The treatments consisted of NPK (recommended rate of 100:50:50 kg ha<sup>-1</sup>), NPK + Zn at 15, 30 or 45 kg ha<sup>-1</sup>, NPK + FYM + Zn at 15, 30 or 45 kg ha<sup>-1</sup>. N was applied at transplanting (50 kg ha<sup>-1</sup>), tillering (25 kg ha<sup>-1</sup>) and panicle initiation stages (25 kg ha<sup>-1</sup>). P, K and Zn fertilizers were applied during transplanting. The highest grain yield (57.7 q ha<sup>-1</sup>), straw (53.8 mg kg<sup>-1</sup> and grain 44.5 mg kg<sup>-1</sup>) Zn contents and total Zn uptake (575.7 g ha<sup>-1</sup>) were obtained with NPK + FYM + Zn at 45 kg ha<sup>-1</sup>. Straw yield was generally higher with the combination of Zn, FYM and NPK compared to NPK only.

Ramana *et al.* (2006) reported that most of the photosynthetic pathways depend on enzymes and coenzymes which are synthesized by micronutrients. Zn and Fe are essential for several enzymes that regulate metabolic activities in plants. They involved in auxin production, transformation of carbohydrate and regulation of sugar in plants. Increase in growth attributes was mainly due to Zn and Fe application which are involved in the synthesis of growth promoting hormones and the reproduction process of many plants which are vital for grain formation.

Gill and Singh (2009) stated that the foliar use of micronutrients particularly Fe proved highly economical than their soil application.

Keram *et al.* (2012) observed that the significantly higher grain yield and straw yield was achieved by the application of 20 kg Zn ha<sup>-1</sup> with recommended NPK as compare to control and other treatments.

Pooniya and Shivay (2013) reported that among the Zn fertilization treatments, 2.0% ZEU as ZnSO<sub>4</sub>.H<sub>2</sub>O recorded the highest yields over remaining Zn fertilization treatments during both the years. In regards to grain yield, 2.0% ZEU as ZnSO<sub>4</sub>.H<sub>2</sub>O remained on par with 2.0% ZEU as ZnO and soil application of 5 kg Zn ha<sup>-1</sup> through ZnSO<sub>4</sub>.H<sub>2</sub>O. The lowest values of grain and straw yields were recorded with absolute control followed by control (only N)

Tabassum *et al.* (2013) observed that increased yield due to Zn and Fe application was attributed to better performance of growth and yield parameters through adequate availability of major and micro nutrients in soil, which in turn, favourably influenced physiological processes and build up of photosynthates.

Ram *et al.* (2013) observed that among the different micronutrient treatments, soil application of Zn-EDTA @ 1.00 kg ha<sup>-1</sup> followed by foliar spray of Fe-EDTA @ 0.5 kg ha<sup>-1</sup> recorded significantly higher grain yield and straw yield over the single or combined application of Zn-EDTA and Fe-EDTA.

Baishya *et al.* (2015) observed that the highest grain yield of rice (6.25 and 7.08 t/ha in 2013 and 2014, respectively) and straw yield of rice (7.91 and 9.23 t ha<sup>-1</sup> in 2013 and 2014, respectively) was recorded due to spraying of 0.5% ZnSO<sub>4</sub>, which was closely followed by spraying of 2% FeSO<sub>4</sub> but significantly greater than those of 0.1% NaSe and control plots during both the years.

Shivay *et al.* (2015) observed that Three foliar application of Zn-EDTA (at tillering, booting and grain filling) was the best treatment and recorded significantly higher grain yield and straw yield than soil application of ZnSHH or Zn-EDTA and two or a single foliar application of ZnSHH or Zn-EDTA.

Dubey *et al.* (2016) observed that application of Zn substantially increased grain and straw yield and maximum grain and straw yield (56.55 and 79.16 q ha<sup>-1</sup>) was recorded with 10 kg Zn ha<sup>-1</sup>.

Suresh and Salakinkop (2016) observed that the combined soil application of ZnSO<sub>4</sub> and FeSO<sub>4</sub> each @ 25 kg ha<sup>-1</sup> and foliar spray of ZnSO<sub>4</sub> and FeSO<sub>4</sub> @ 0.5 % recorded significantly higher grain yield (3739 kg ha<sup>-1</sup>) and straw yield (5539 kg ha<sup>-1</sup>).

### **2.3 Effect of iron and zinc on nutrient uptake by paddy**

Pathak *et al.* (1975) reported that increase in zinc content and uptake of nutrients by rice due to zinc fertilization.

Singh (1976) stated that the increasing P rates increased P contents in leaves and stems, Zn decreased them by 26 per

cent in leaves and 12 per cent in stem. P uptake increased with applied P and or Zn due to increased dry matter production. Zn uptake increased with lower dose of P, but decreased with higher P rate. The main site of Zn accumulation in plant was the stem.

Sharma *et al.* (1986) reported that Zn concentration in plant tissues and Zn uptake by grain and straw of rice increased significantly with the Zn application.

Sahay *et al.* (1992) conducted field trials on paddy and wheat with four levels of Zn and B with the recommended rate of NPK. The concentration and uptake of Zn in grain and straw of paddy were significantly enhanced by Zn application. Zn concentration in grain ranged from 18.24 to 27.13 ppm and in straw from 18.34 to 25.28 ppm.

Mali and Sheikh (1993) Studied the effect of zinc sources (zinc sulphate, zincated suphala) with or without FYM applied to *kharif* (monsoon) rice and found that yield and N, P and Zn contents of both crops increased with Zn application and were highest with zincated suphala.

Dixit and Patro (1994) reported that the total NPK and Zn uptake increased with NPK and zinc application except P uptake which decreased slightly with Zn application. Uptake of NPK and Zn increased with increased plant density.

Singh and Sharma (1994) observed that 20 kg ZnSO<sub>4</sub>, 0.5 kg chelated Zn or 0.5 kg Zn-EDTA ha<sup>-1</sup> as a basal application, top dressing or in 3 foliar sprays of 0.5%, 0.1% and 0.01% for the 3 sources, respectively to rice cv. Sarju-52.

Zinc uptake was highest with a basal dose of 20 kg ZnSO<sub>4</sub> ha<sup>-1</sup> as a top dressing or 3 foliar sprays gave the lowest zinc uptake.

Nandram (1996) reported that the addition of zinc and FYM along with 100% NPK increased uptake of Zn from the soil.

Kumar and Singh (1997) conducted a field experiment during *kharif* (monsoon) 1990 at Bihar Agricultural College Farm, Sabour, rice cv. Sita was given 0, 12.5 or 25 kg ZnSO<sub>4</sub> ha<sup>-1</sup> by soil application in the nursery or 3-week-old seedlings were sprayed with 0.5% ZnSO<sub>4</sub>, or seedling roots were dipped in 2% ZnO solution. Of the nursery treatments, dipping roots in ZnO gave the highest Zn concentration at all growth stages. Zn concentration was greatest at active tillering and then gradually decreased, with the post transplanting treatment given the highest Zn concentration at tillering being soil application of 25 kg ZnSO<sub>4</sub>.

Trivedi *et al.* (1998) summarized the results of a field experiment conducted on Vertic Ustochrept on rice. The treatments consisted 4 levels of Zn (0, 5.6, 11.2 and 16.8 kg Zn ha<sup>-1</sup>) through ZnSO<sub>4</sub>.7H<sub>2</sub>O. Zinc uptake increased significantly with successive rice in Zn levels up to 11.2 kg ha<sup>-1</sup>.

Ganghah *et al.* (1999) reported that application of N, P, K with micronutrients Zn and Fe are known to increase the uptake or content of N, P, K, Zn and Fe.

Patnaik and Raj (1999) reported that the soil application of 75 kg ZnSO<sub>4</sub> gave the highest cumulative effect. Zinc content in the index leaf samples increased with the increase in the ZnSO<sub>4</sub> application. The uptake in the zinc sulphate treated plots was significantly more than the control plot.

Verma and Tripathi (2010) reported that the zinc and iron content in rice grains were recorded maximum with their separate application and minimum under control, whereas combined and sequential applications of Zn-EDTA and Fe-EDTA slightly decreased Zn and Fe concentrations in grains as compared to their separate applications.

Keram *et al.* (2012) observed that the maximum total nutrient uptake (N-123.19 kg ha<sup>-1</sup>, K-90.86 kg ha<sup>-1</sup> and Zn-327.74 g ha<sup>-1</sup>) was achieved by the application of 20 kg Zn ha<sup>-1</sup> with recommended NPK as compare to control and other treatments, while the total P uptake was decline with increasing levels Zn.

Pooniya and Shivay (2013) reported that the significantly higher N uptake in grain, straw and total by basmati rice was obtained with *Sesbania aculeate* GM and 2.0% ZEU (zinc enriched urea) as ZnSO<sub>4</sub>.H<sub>2</sub>O and these treatments remained superior to the rest of summer GMs and Zn fertilization treatments in both the years of study. Also the same treatment recorded significantly higher K uptake in grain, straw and total (grain + straw) of basmati rice. The total K uptake in basmati rice was almost 23-25 times higher than that in grain. A similar trend was also recorded with respect of S uptake by basmati rice. Also he reported that among the Zn

fertilization treatments, soil application of 5 kg Zn ha<sup>-1</sup> through ZnSO<sub>4</sub>.H<sub>2</sub>O and 0.2% foliar spray of ZnSO<sub>4</sub>.H<sub>2</sub>O recorded the highest K and Zn uptake ratio in basmati rice grain.

Ram *et al.* (2013) observed that application of Zn-EDTA @ 1 kg ha<sup>-1</sup> in soil followed by Fe-EDTA @ 0.5 kg ha<sup>-1</sup> as foliar spray in two splits recorded maximum N, P and K content in grain of rice and proved superior over other treatments whereas, it remained at par with Zn-EDTA @ 0.5 kg ha<sup>-1</sup> followed by @ 0.5 kg ha<sup>-1</sup> Fe-EDTA as foliar application. The zinc and iron content in rice grains were recorded maximum with their separate application.

Shivay *et al.* (2015) observed that Three foliar application of Zn-EDTA (at tillering, booting and grain filling) was the best treatment and recorded significantly higher concentration and uptake of Zn in grain and straw of Basmati rice than soil application of ZnSHH or Zn-EDTA and two or a single foliar application of ZnSHH or Zn-EDTA.

Baishya *et al.* (2015) observed that micronutrients fortification did not show significant effect on increasing the N, P and K content in rice. However, foliar application of different micronutrients exerted significant effect on their respective contents in rice grain under the study. The crop receiving 0.5% ZnSO<sub>4</sub> increased Zn content in grain over that of the other treatments. Similarly, spraying of 2.0% FeSO<sub>4</sub> and 0.1% NaSe significantly increased the Fe and Se contents in rice grain, respectively.

Dubey *et al.* (2016) observed that the N, P, K, S and Zn uptake increased significantly with the use of nitrogen, sulphur and zinc.

#### **2.4 Effect of iron and zinc on chemical properties at harvest**

Keram *et al.* (2012) observed that there is no appraisal change in soil pH, EC, organic carbon and CaCO<sub>3</sub>, but the status of DTPA-extractable Zn of soil was improved remarkably due to rational Zn fertilization combined with recommended NPK.

Radhika *et al.* (2013) observed that the available nutrients in the soil *viz.*, Fe, Mn, Zn, Cu and B (3.44, 7.86, 2.43, 1.68 and 0.53 ppm) were also significantly increased with 1.0 percent kiecite application as compared to control (2.18, 4.87, 1.83, 0.98 and 0.52) respectively.

### **3. MATERIAL AND METHODS**

A pot culture experiment was conducted in wire house of department of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur during *Kharif* season of 2016-2017. The details regarding the materials used and methodology followed during the course of the present investigation have been given in this chapter.

#### **3.1 Materials**

##### **3.1.1. Location of experimental site**

College of Agriculture, Kolhapur is located near National Highway No. 4 and Kolhapur-Kagal road, about 5 km South-East of Kolhapur city. The location of the campus is between 16° 42' N latitude and between 74° 14' E longitudes. It's elevation is 548 m above the mean sea-level.

##### **3.1.2. Climate and weather**

The College of Agriculture, Kolhapur comes under the sub-montane zone with annual rainfall from 700 to 2500 mm. the average annual rainfall is 1057 mm out of which 80 percent receives from south west monsoon in June to September while rest of rainfall receives in the month of October and November from North West monsoon.

##### **3.1.3. Soil**

Earthen pots were filled with 10 kg iron and zinc deficient soil in which recommended dose of FYM (5 t ha<sup>-1</sup>) was mixed. The soil used for filling the earthen pots was

collected from farm of Animal Science and Dairy Science Division, College of Agriculture Kolhapur.

**Table 1: Chemical properties of experimental soil (Initial)**

<b>Parameters</b>	<b>Values</b>
<b>A) Soil physical properties</b>	
Fine sand (%)	35.40
Silt (%)	28.00
Clay (%)	36.60
Soil texture	Silt clay loam
<b>B) Soil chemical properties</b>	
pH (1:2.5, soil : water)	7.6
EC (dSm <sup>-1</sup> )	0.26
Organic carbon (%)	0.64
Per cent calcium carbonate equivalent	5.22
Available nitrogen (kg ha <sup>-1</sup> )	235.90
Available phosphorus (kg ha <sup>-1</sup> )	18.48
Available potassium (kg ha <sup>-1</sup> )	138.74
DTPA Extractable Micronutrients (ppm)	
Available Fe	3.92
Available Mn	1.81
Available Zn	0.55
Available Cu	0.16

#### **3.1.4. Selection of crop**

The paddy (Cv. Bhogawati) was selected as a test crop during *kharif* season 2016.

#### **3.1.5. Experimental layout**

The present investigation was carried out in Completely Randomized Block Design. Treatments comprised of two levels with two sources of each iron and zinc. The sources of iron as FeSO<sub>4</sub>, Fe-EDTA and for zinc as ZnSO<sub>4</sub>, Zn-EDTA which are replicated thrice along with one control.

**Table 2. The treatment details and their symbols**

Sr. No.	Treat. No.	Treatment Details	Quantity used for spraying at tillering and panicle stage (g/100 mL)			
			Fe-EDTA	Zn-EDTA	FeSO <sub>4</sub>	ZnSO <sub>4</sub>
1	T1	Control	-	-	-	-
2	T2	GRDF	-	-	-	-
3	T3	GRDF + Fe-EDTA @ (0.1%)	0.83	-	-	-
4	T4	GRDF + Fe-EDTA @ (0.5%)	4.16	-	-	-
5	T5	GRDF + Zn-EDTA @ (0.1%)	-	0.83	-	-
6	T5	GRDF + Zn-EDTA @ (0.5%)	-	4.16	-	-
7	T7	GRDF + Fe-EDTA + Zn-EDTA each @ (0.1%)	0.83	0.83		
8	T8	GRDF + Fe-EDTA + Zn-EDTA each @ (0.5%)	4.16	4.16	-	-
9	T9	GRDF + Fe @ (0.1%)	-	-	0.50	-
10	T10	GRDF + Zn @ (0.1%)	-	-	-	0.43
11	T11	GRDF + Fe @ (0.5%)	-	-	2.52	-
12	T12	GRDF + Zn @ (0.5%)	-	-	-	2.19
13	T13	GRDF + Fe + Zn each @ (0.1%)	-	-	0.50	0.43
14	T14	GRDF + Fe + Zn each @ (0.5%)	-	-	2.52	2.19

### 3.1.6. Details of Cultivation Practices:

**Table 3: Schedule of practices carried out in experiment**

<b>Sr. No.</b>	<b>Research Work to be carried out</b>	<b>Date of Operation</b>
1	Collection of Zn and Fe deficient soil	25 May 2016
2	Soil application of fertilizers.	
	Basal dose (40% N, 100% P and K)	25 June 2016
	1 month DAS (40% N)	28 July 2016
	2 month DAS (20% N)	27 Aug 2016
3	Sowing of paddy.	27 June 2016
4	Foliar application of iron and zinc.	
	At tillering stage	29 July 2016
	At panicle stage	28 Aug 2016
5	Growth and yield observations.	
	Growth observation- Plant height	29 Oct 2016
	- No. of tillers	29 Oct 2016
	Yield observation - Grain yield	04 Nov 2016
- Straw Yield	04 Nov 2016	
6	Plant and soil sampling at harvest.	04 Nov 2016

#### 3.1.6.2. Application of fertilizers

The recommended fertilizers dose of 100:50:50 (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) was applied. A basal dose of 40:50:50; N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup> was applied at the time of sowing through urea, single super phosphate and muriate of potash in all the treatments excluding control. The second split dose of nitrogen i.e. 40 kg N ha<sup>-1</sup> was applied at tillering stage and

third split dose of nitrogen i.e. 20 kg N ha<sup>-1</sup> was applied at panicle initiation stage through urea.

**Table 4: Required fertilizers:**

<b>Recommended dose for rice</b>	<b>At the time of sowing (g/pot)</b>	<b>First split of urea 40% (g/pot)</b>	<b>Second split of urea 20% (g/pot)</b>
N 100 (kg ha <sup>-1</sup> )	0.48 (Urea)	0.48 (Urea)	0.24(Urea)
P <sub>2</sub> O <sub>5</sub> 50 (kg ha <sup>-1</sup> )	1.40 (SSP)	-	-
K <sub>2</sub> O50 (kg ha <sup>-1</sup> )	0.46 (MOP)	-	-

### **3.1.6.3. Sowing**

Sowing of rice seeds was done in June 2016 in pots. There was sown two seeds per hill and ten seeds per pot.

### **3.1.6.4. Foliar application of zinc and iron**

Different iron and zinc sources as FeSO<sub>4</sub>, ZnSO<sub>4</sub>, Fe-EDTA and Zn-EDTA were applied as foliar spray at different growth stages (tillering and panicle stage) of rice.

### **3.1.6.5. Irrigation**

Optimum soil moisture was maintained in each treatment by periodically watering the pots during the crop period as per requirements considering rainfall and crop growth stages.

## 3.2. Observations

### 3.2.1. Plant observations:

**Table 5: Details of plant observations.**

Sr. No.	Observation
A	<p>Growth studies</p> <p>1.Pre-harvest studies: a. Plant height b. Total no. of productive tillers</p> <p>2.Post harvest studies: a. Grain yield (g pot<sup>-1</sup>) b. Straw yield (g pot<sup>-1</sup>) c. Dry matter per pot</p>

#### 3.2.1.1A. Growth studies

##### 1. Pre-harvest studies

###### a. Plant height

The plant heights of five plants were measured from the ground level up to the tip of main panicle at maturity and the average height of plants was expressed in centimetres.

###### b. Total number of productive tillers per pot

The number of productive tillers per pot was recorded at harvest.

##### 2. Post-harvest studies

###### a. Grain yield

The grains from each panicle were removed, the produce from each pot were sun dried for seven days and their final air-dried weight per pot was recorded in gram.

**b. Straw yield**

The straw yield per pot was obtained by weighing the air dried straw and chaff which remained after removal of grains. It was considered as straw yield per pot (g).

**c. Dry matter per pot**

The chopped plant material was kept in perforated brown paper bags, suitably labelled and dried to constant weight in thermo statistically controlled oven at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  temperature. Then dry weight from respective treatments was recorded.

**3.3. Methods**

The analytical work was done in the research laboratory of the Division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur during the academic year 2016-2017. The following analytical methods were employed.

**3.3.1. Soil Analysis**

Before sowing and after harvest of crop, pot wise representative soil samples were collected and analysed by adopting standard procedures.

**Table 6: Methods used for soil analysis :**

<b>Sr. No.</b>	<b>Parameters</b>	<b>Methods used</b>	<b>References</b>
1.	pH (1:2.5; Soil : Water)	Potentiometry	Jackson (1973)
2.	EC (1:2.5; Soil : Water)	Conductometry	Jackson (1973)
3.	Organic Carbon	Wet oxidation	Nelson and Sommers (1982)
4.	Per cent CaCO <sub>3</sub> equivalent	Rapid titration	Piper (1966)
5.	Available Nitrogen	Alkaline permanganate	Subbiah and Asija (1956)
6.	Available Phosphorus	Olsen (0.5 M sodium bicarbonate) (pH-8.5)	Olsen and Watanable (1965)
7.	Available Potassium	Flame photometry, 1 N neutral ammonium acetate (pH-7.0)	Jackson (1973)
8.	DTPA Extractable Micronutrients (Fe, Mn, Zn, Cu)	Atomic Absorption Spectrophotometer	Lindsay and Norvell (1978)

### **1) Soil reaction ( pH )**

The soil pH was measured with the help of pH meter having glass electrode and calomel electrodes using 1:2.5, soil: water ratio as described by Jackson (1973).

### **2) Electrical conductivity (dS m<sup>-1</sup>)**

It was determined with the help of conductivity meter using soil: water ratio 1:2.5 Jackson (1973).

### **3) Organic carbon (%)**

Organic carbon in soil (0.5 mm sieved) was determined by wet oxidation as described by Nelson and Sommers (1982).

#### **4) Calcium carbonate (%)**

Calcium carbonate in soil was determined by Rapid titration method as described by Piper (1966).

#### **5) Available nitrogen (kg ha<sup>-1</sup>)**

It was determined by Alkaline permagnate method (0.32% KMnO<sub>4</sub>) as described by Subbiah and Asija (1956).

#### **6) Available phosphorus (kg ha<sup>-1</sup>)**

Available phosphorus was determined by Olsen's method using 0.5 M sodium bicarbonate alkaline extractant at pH 8.5. The soil: extractant ratio was 1:20 and the shaking time 30 minutes. Phosphorus in the extract was determined colorimetrically by using spectrophotometer at 660 nm wavelength.

#### **7) Available potassium (kg ha<sup>-1</sup>)**

It was extracted with neutral normal ammonium acetate (NH<sub>4</sub>OAc, pH 7.0) and the soil: extractant ratio was 1:5 and shaking time was 5 minutes. Potassium in soil was determined flame photometrically as described by Jackson (1973).

#### **8) Available micronutrients**

Micronutrients from soil samples were determined by Atomic Absorption Spectrophotometer using DTPA extractant as described by Lindsay and Norvell (1978).

#### **3.3.2. Plant analysis**

The samples taken at tillering stage were analysed for chlorophyll content. The treatment wise grain and straw samples were collected at harvesting stage and analysed to estimate total nitrogen, phosphorus, potassium and

micronutrients (Fe, Mn, Zn, Cu) content after oven drying and grinding the samples.

**Table 7: Methods used for plant analysis**

<b>Parameters</b>	<b>Methods</b>	<b>References</b>
Total N	Microkjeldahl (Catalyst mixture)	Parkinson & Allen (1975)
Total P	Vanadomolybdate yellow colour in nitric acid system (Triacid digestion)	Jackson (1973)
Total K	Flame photometry (Triacid digestion)	Chapman and Pratt (1961)
Micronutrients (Fe, Mn, Zn, Cu)	Atomic absorption spectrophotometry (diacid digestion)	Zoroski and Bureau (1977)

## **2) Total Nitrogen**

The plant samples (0.2 g each) were digested by using concentrated  $H_2SO_4$  (5 ml) and  $H_2O_2$  (5 ml). The volume was made by distilled water to 100 ml after digestion of sample. A suitable aliquot was taken for nitrogen distillation and nitrogen was determined by Microkjeldahl method (Parkinson and Allen, 1975).

## **3) Total phosphorus**

The plant samples (0.2 g each) were wet digested with sulphuric acid, nitric acid and perchloric acid. The volume was made to 100 ml with distilled water after digestion and was used for determination of phosphorus. The total phosphorus was determined by using triacid extract and the yellow colour was developed with combined nitric acid

vanadomolybdate reagent. Phosphorus was determined colorimetrically by using spectrophotometer at 420 nm wavelength (Jackson, 1973).

#### **4) Total micronutrients (Fe, Mn, Zn, Cu)**

The plant samples (0.2 g each) were wet digested with nitric acid and perchloric acid. The volume was made to 100 ml with distilled water after digestion and that extractant was used for determination of micronutrients by using Atomic Absorption Spectrophotometer described by Zoroski and Bureau (1977)

#### **3.3.3. Uptake of nutrients by the crop**

The uptake of nitrogen, phosphorus, potassium and micronutrients ( $\text{mg pot}^{-1}$ ) was worked out by multiplying the percentage of these nutrients in grain and straw with the corresponding dry matter yields of the respective constituent.

#### **3.4. Statistical analysis**

The experimental data were analyzed statistically by applying the technique of "Analysis of variance" and significance was tested by variance ratio i.e. F value at 5 per cent level of significance as described by Panse and Sukhatme, (1967). Standard error of mean (S.E.) and critical difference (CD) was worked out to evaluate critical differences between treatment means.

## 4. RESULTS AND DISCUSSION

The results of a pot culture experiment on “Foliar application of iron and zinc on growth, yield and nutrient uptake of paddy” are presented and discussed under the following heading.

4.1 Effect of different treatments on growth and yield of paddy.

4.2 Effect of different treatments on per cent nutrient content of N, P, K in grain and straw of paddy.

4.3 Effect of different treatments on total uptake of nutrients of N, P, K by paddy.

4.4 Effect of different treatments on micronutrients (Fe, Mn, Zn and Cu) contents in grain and straw of paddy.

4.5 Effect of different treatments on total uptake of Micronutrients (Fe, Mn, Zn and Cu) by paddy.

4.6 Effect of different treatments on chemical properties of soil.

### **4.1 Effect of different treatments on growth and yield of paddy.**

#### **4.1.1 Effect of different treatments on plant height and number of tillers of paddy:**

The data in respect of plant height and number of tillers per pot as influenced by foliar application of zinc and iron is presented in Table 8.

The plant height of paddy at maturity stage was recorded and it was found that the treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar spray with GRDF) significantly increase plant height (63.59 cm) over the rest of treatments. However the treatment T4, T6, T7 and T14 were at par with each other.

The treatment No.T1 (control) without application of fertilizers and micronutrient spray recorded lowest height (55.26 cm).

The increase in plant height of paddy crop might be due to foliar application of Fe and Zn, they are essential for several biochemical processes such as cytochrome and nucleotide synthesis, enzyme activation, chlorophyll production, increase seed and stalk maturation.

The data in respect of number of tillers showed that there is significant difference in number of tillers due to various treatments. The treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar spray with GRDF) showed significantly higher number of tillers (25.66 pot<sup>-1</sup>) than the rest of treatments. However treatment T6, T7 and T11 were at par with each other (22.33, 23.00 and 22.00 respectively). The lowest number of tillers was recorded by treatment T1 (control i.e. 11.53).

The similar results were reported that Fe and Zn as foliar through Fe-EDTA and Zn-EDTA recorded relatively large plant height and number of tillers by Ram *et al.* (2013), Kulandaivel *et al.* (2004), Ghatak *et al.* (2005), Rakesh *et al.* (2012), Saha *et al.* (2013), Radhika *et al.* (2013), and Shivay *et al.* (2015).

#### **4.1.2 Effect of different treatments on grain and stover yield of paddy.**

The data in respect of grain and stover yield of paddy (g pot<sup>-1</sup>) as influenced by foliar application of zinc and iron is presented in Table 8.

The data in respect of yield revealed that the yield differences in different treatments were found statistically

significant. The treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar spray with GRDF) recorded highest grain yield (35.54 g pot<sup>-1</sup>) which was significantly superior to rest of the treatments. However in grain yield treatment T4, T14 are found to be at par with each other. The treatment T1 (control) recorded lowest grain yield (14.52 g pot<sup>-1</sup>).

Similarly the treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar spray with GRDF) recorded highest straw yield (39.01 g pot<sup>-1</sup>) which was significantly superior to rest of the treatments. However in straw yield treatment T3, T4, T7, T13, T14 are found to be at par with each other. The treatment T1 (control) recorded lowest straw yield (16.79 g pot<sup>-1</sup>).

The increase in grain yield with Fe-EDTA and Zn-EDTA foliar spray each @ 0.5% with GRDF significantly influenced the grain yield, it might be due to combined effect of many yield components including higher number of tillers. Partitioning of photosynthesis towards them is responsible for increased yield. The FYM sources also improve the content of Fe and Zn by supplying chelating agents, which helps in maintaining the solubility of micronutrients including Fe and Zn.

The increase in grain and straw yield with iron and zinc application is attributed to increase in number of tillers pot and improved nutrition of paddy due to foliar application of iron and zinc. Similar results reported as increase in grain and straw yields of paddy by foliar application of Fe and Zn as Fe-EDTA and Zn-EDTA by Ram *et al.* (2013) and Shivay *et al.* (2015), Singh and Sharma (1994).

**Table 8: Effect of different treatments on growth and yield of paddy.**

<b>Treatment detail</b>	<b>Plant height (cm)</b>	<b>No. of tillers (pot<sup>-1</sup>)</b>	<b>Grain yield (g pot<sup>-1</sup>)</b>	<b>Stover yield (g pot<sup>-1</sup>)</b>
<b>T1:</b> Control	55.26	11.53	14.52	16.79
<b>T2:</b> GRDF	58.20	20.26	28.28	31.10
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	61.26	19.66	30.42	36.50
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	62.22	21.66	33.66	37.02
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	61.10	20.66	28.99	31.88
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	62.26	22.33	27.96	30.75
<b>T7:</b> GRDF + Fe-EDTA +Zn-EDTA each @ 0.1%	62.14	23.00	32.14	35.99
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	63.59	25.66	35.54	39.01
<b>T9:</b> GRDF + Fe @ 0.1%	61.07	21.33	31.19	34.30
<b>T10:</b> GRDF + Zn @ 0.1%	61.10	21.26	29.80	32.78
<b>T11:</b> GRDF + Fe @ 0.5%	61.39	22.00	30.33	33.36
<b>T12:</b> GRDF + Zn @ 0.5%	61.28	20.00	30.42	33.46
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	61.27	20.00	31.30	36.64
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	62.37	21.66	32.71	35.98
<b>SE ±</b>	0.12	0.41	0.33	0.33
<b>CD (P=0.05)</b>	0.36	1.21	0.97	0.96

#### **4.2 Effect of different treatments on per cent nutrient content of N, P, K in grain and stover of paddy.**

The data in respect of effect of foliar application of iron and zinc on per cent nutrient content by paddy is presented in Table 9.

The N, P, K content in grain of paddy increased significantly due to foliar application of iron and zinc with general recommended dose of fertilizers. Treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar application with GRDF) recorded highest N, P, K content in grain (1.27, 0.30 and 0.39 respectively). However in respect of N content in grain treatment T11, T12, T14, in respect of P content in grain treatment T4, T7, T11, T14 and in respect of K content in grain treatment T14 were at par with treatment T8.

The N, P, K content in straw of paddy increased significantly due to foliar application of iron and zinc with recommended dose of N, P, K. Treatment T8 (Fe-EDTA + Zn-EDTA each @ 0.5% foliar spray with GRDF) recorded highest N, P, K content in straw (0.34, 0.14 and 1.46 per cent respectively). However in respect of nutrient content in straw, N content in straw treatment T6 was at par with treatment T8. But in respect of P and K content in straw treatment T8 was significantly superior to rest of all treatments including control.

Application of N, P, K with micronutrients Fe and Zn are known to increase the content of N, P, K, Zn and Fe due to increased metabolic activities in plant.

Similar results reported as increase in per cent nutrient content of N, P and K of paddy by foliar application of iron and zinc as Fe-EDTA and Zn-EDTA @ 0.5% by Ram, *et al.* (2013), Shivay, *et al.* (2015), Verma and Tripathi (2010) and Sharma, *et al.* (1986).

**Table 9: Effect of different treatments on per cent nutrient content of N, P, K in grain and stover of paddy.**

Treatment detail	% nutrient content					
	Grain			Stover		
	N	P	K	N	P	K
<b>T1:</b> Control	1.22	0.25	0.34	0.20	0.10	1.21
<b>T2:</b> GRDF	1.25	0.25	0.35	0.25	0.10	1.24
<b>T3:</b> GRDF +Fe-EDTA @0.1%	1.25	0.26	0.35	0.23	0.11	1.34
<b>T4:</b> GRDF +Fe-EDTA @ 0.5%	1.25	0.28	0.35	0.27	0.12	1.38
<b>T5:</b> GRDF+ Zn-EDTA @ 0.1%	1.24	0.26	0.35	0.21	0.12	1.32
<b>T6:</b> GRDF+ Zn-EDTA @ 0.5%	1.25	0.27	0.35	0.33	0.12	1.34
<b>T7:</b> GRDF+ Fe-EDTA + Zn-EDTA each @ 0.1%	1.25	0.29	0.37	0.26	0.12	1.33
<b>T8:</b> GRDF +Fe-EDTA + Zn-EDTA each @ 0.5%	1.27	0.30	0.39	0.34	0.14	1.46
<b>T9:</b> GRDF + Fe @ 0.1%	1.25	0.26	0.34	0.22	0.12	1.25
<b>T10:</b> GRDF + Zn @ 0.1%	1.25	0.26	0.34	0.21	0.12	1.24
<b>T11:</b> GRDF + Fe @ 0.5%	1.26	0.27	0.35	0.24	0.12	1.30
<b>T12:</b> GRDF + Zn @ 0.5%	1.26	0.26	0.35	0.22	0.11	1.28
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	1.25	0.26	0.34	0.22	0.11	1.30
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	1.26	0.27	0.38	0.26	0.12	1.35
<b>SE ±</b>	0.001	0.001	0.001	0.005	0.004	0.004
<b>CD (P=0.05)</b>	0.002	0.003	0.002	0.015	0.013	0.012

### **4.3 Effect of different treatments on total uptake of nutrients of N, P, K by paddy.**

The data in respect of effect of foliar application of iron and zinc on total nutrient uptake by plant is presented in Table 10.

The data in respect of total uptake of N, P, K revealed that the total uptake differences in different treatments were found statistically significant. The treatment T8 (Fe-EDTA and Zn-EDTA each @ 0.5% foliar spray with GRDF) recorded highest total N, P, K uptake (588.50, 164.10 and 712.57 mg pot<sup>-1</sup> respectively) which was significantly superior to rest of the treatments. However in respect of N treatments T4 (521.37 mg pot<sup>-1</sup>), T14 (510.03 mg pot<sup>-1</sup>), in respect of P treatments T4 (138.07 mg pot<sup>-1</sup>), T7 (135.47 mg pot<sup>-1</sup>), T14 (132.03 mg pot<sup>-1</sup>) and in respect of K, treatments T4 (632.00 mg pot<sup>-1</sup>), T14 (618.10 mg pot<sup>-1</sup>) are found to be at par with each other. The treatment T1 (control) recorded lowest total uptake of N, P, K (210.93, 53.07 and 251.20 mg pot<sup>-1</sup> respectively). Application of N, P, K with micronutrients, Fe and Zn are known to increase the uptake of N, P, K, Zn and Fe due to increased metabolic activities in plant.

Similar results reported as increase in total uptake of N, P and K of paddy by foliar application of iron and zinc by Ram *et al.* (2013) and Shivay *et al.* (2015), Verma and Tripathi (2010) and Sharma, *et al.* (1986).

**Table 10: Effect of different treatments on total uptake of N, P and K by paddy.**

Treatment detail	N	P	K
	mg pot <sup>-1</sup>		
<b>T1:</b> Control	210.93	53.07	251.20
<b>T2:</b> GRDF	430.30	103.87	483.50
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	463.03	122.43	596.03
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	521.37	138.07	632.00
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	427.77	113.80	522.67
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	425.50	113.23	512.43
<b>T7:</b> GRDF + Fe-EDTA +Zn-EDTA each @ 0.1%	494.63	135.47	598.07
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	588.50	164.10	712.57
<b>T9:</b> GRDF + Fe @ 0.1%	466.90	122.13	536.30
<b>T10:</b> GRDF + Zn @ 0.1%	441.67	114.37	509.03
<b>T11:</b> GRDF + Fe @ 0.5%	463.80	121.73	540.33
<b>T12:</b> GRDF + Zn @ 0.5%	458.50	118.40	535.87
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	475.17	124.20	577.90
<b>T14:</b> GRDF + Fe + Zn each@ 0.5 %	510.03	132.03	618.10
<b>SE ±</b>	4.17	2.11	4.93
<b>CD (P=0.05)</b>	12.10	6.12	14.29

#### **4.4 Effect of different treatments on micronutrients (Fe, Mn, Zn and Cu) content in grain and stover of paddy.**

The data in respect of micronutrient content of Fe, Mn, Zn, Cu is presented in Table 11, and it was revealed that the micronutrient content in grain and straw significantly influenced by foliar application of iron and zinc with different sources and concentrations, except Cu content in grain and straw, and Mn content in straw.

The data in respect of Fe content in grain showed that there was significant difference in Fe content in grains due to various treatments. The treatment T4 (Fe-EDTA @ 0.5% with GRDF) recorded significantly maximum Fe content in grains ( $6.85 \text{ mg kg}^{-1}$ ) over rest of the treatments. The data in respect of Mn content in grains showed that, treatment T2 (GRDF) recorded significantly superior Mn content in grains ( $0.26 \text{ mg kg}^{-1}$ ) over rest of the treatments. The data in respect of Zn content in grains showed that, treatment T6 (Zn-EDTA @ 0.5% foliar application with GRDF) recorded highest Zn content ( $0.17 \text{ mg kg}^{-1}$ ) and treatments T4, T5, T7, T8, T10, T12, T14 ( $0.08$ ,  $0.12$ ,  $0.09$ ,  $0.11$ ,  $0.11$ ,  $0.14$  and  $0.09 \text{ mg kg}^{-1}$  respectively) were at par with treatment T6. The data in respect of Cu not showed significant difference in various treatments.

The data in respect of micronutrient content in straw revealed that Fe, Zn content in straw as significantly influenced by foliar application of iron and zinc with different sources and concentrations. But the data in respect of Mn and Cu content in straw showed that there was no significant difference in various treatments.

However the data in respect of Fe content in straw showed that, treatment T4 (Fe-EDTA @ 0.5% with GRDF) recorded significantly superior Fe content ( $7.23 \text{ mg kg}^{-1}$ ) to all over the treatments, and the data in respect of Zn content in straw showed that, treatment T6 (Zn-EDTA @ 0.5% foliar application with GRDF) recorded highest Zn content ( $0.19 \text{ mg kg}^{-1}$ ) in straw and the treatments T12 (0.17), T5 (0.16) were at par with each other.

Similar results reported as maximum content of micronutrients (Fe, Mn, Zn and Cu) in grain and stover of paddy by separate foliar application of Fe-EDTA and Zn-EDTA than their combined application by Ram *et al.* (2013), Shivay *et al.* (2015), Verma and Tripathi (2010) and Sharma, *et al.* (1986).

**Table 11: Effect of different treatments on micronutrients (Fe, Mn, Zn and Cu) content in grain and stover of paddy.**

Treatment detail	Micronutrient conc. in grain				Micronutrient conc. in stover			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
	mg kg <sup>-1</sup>				mg kg <sup>-1</sup>			
<b>T1:</b> Control	3.79	0.13	0.05	0.12	3.89	0.09	0.05	0.09
<b>T2:</b> GRDF	4.04	0.26	0.05	0.10	4.20	0.20	0.07	0.14
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	5.12	0.13	0.07	0.10	6.83	0.18	0.09	0.16
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	6.85	0.14	0.08	0.08	7.23	0.22	0.11	0.17
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	4.09	0.08	0.12	0.12	5.42	0.17	0.16	0.24
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	4.32	0.09	0.17	0.11	6.02	0.19	0.19	0.18
<b>T7:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.1%	5.12	0.11	0.09	0.15	6.09	0.20	0.13	0.14
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	6.56	0.05	0.11	0.09	6.39	0.22	0.15	0.14
<b>T9:</b> GRDF + Fe @ 0.1%	5.07	0.14	0.06	0.18	5.83	0.13	0.09	0.16
<b>T10:</b> GRDF + Zn @ 0.1%	4.03	0.07	0.11	0.10	4.83	0.20	0.14	0.16
<b>T11:</b> GRDF + Fe @ 0.5%	6.64	0.09	0.07	0.11	6.92	0.17	0.09	0.24
<b>T12:</b> GRDF + Zn @ 0.5%	4.25	0.08	0.14	0.12	5.70	0.18	0.17	0.17
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	5.03	0.21	0.07	0.11	5.47	0.19	0.11	0.22
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	6.31	0.18	0.09	0.14	5.66	0.21	0.14	0.20
<b>SE ±</b>	0.01	0.03	0.03	0.01	0.01	0.02	0.004	0.03
<b>CD (P=0.05)</b>	0.04	0.12	0.09	NS	0.03	NS	0.017	NS

#### **4.5. Effect of different treatments on total uptake of micronutrients (Fe, Mn, Zn and Cu) by paddy.**

The data in respect of effect of foliar application of iron and zinc on total uptake of micronutrients (Fe, Mn, Zn and Cu) reported in Table 12, revealed that total uptake of micronutrients significantly influenced by foliar application of iron and zinc with different sources and concentrations.

The data in respect of total uptake of Fe in plant showed that there was significant difference in total uptake of Fe in plants due to various treatments. The treatment T4 (Fe-EDTA @ 0.5% with GRDF) recorded significantly superior uptake of Fe in plants ( $0.496 \text{ mg pot}^{-1}$ ) over rest of the treatments, however treatment T3 ( $0.404 \text{ mg pot}^{-1}$ ) and T14 ( $0.413 \text{ mg pot}^{-1}$ ) were at par with each other. The treatment T1 (control) recorded lowest total uptake of Fe ( $0.120 \text{ mg pot}^{-1}$ ).

The data in respect of total uptake of Mn in plants showed that treatment T13 (FeSO<sub>4</sub> + ZnSO<sub>4</sub> each @ 0.1% foliar application with GRDF) and T14 (FeSO<sub>4</sub> + ZnSO<sub>4</sub> each @ 0.5% foliar application with GRDF) recorded significantly higher uptake of Mn in plants ( $0.013 \text{ mg pot}^{-1}$  each), and the treatments T2, T3, T4, T5, T6, T7 and T10 ( $0.012$ ,  $0.010$ ,  $0.012$ ,  $0.010$ ,  $0.009$ ,  $0.011$  and  $0.012 \text{ mg pot}^{-1}$  respectively) were at par with treatments T13 and T14. The treatment T1 (control) recorded lowest total uptake of Mn ( $0.003 \text{ mg pot}^{-1}$ ).

The data in respect of total uptake of Zn in plants showed that treatment T6 (Zn-EDTA @ 0.5% foliar spray with GRDF) recorded significantly higher uptake of Zn in plants ( $0.010 \text{ mg pot}^{-1}$ ), and treatments T8, T12 ( $0.009 \text{ mg pot}^{-1}$  each)

were at par with treatment T6. The treatment T1 (control) recorded lowest total uptake of Zn ( $0.002 \text{ mg pot}^{-1}$ ).

The in respect of Cu in plants showed that treatments T9, T11, T13, T14 recorded significantly higher uptake Cu ( $0.011 \text{ mg pot}^{-1}$ ) in plants, and all other treatments were at par with treatments T9, T11, T13, T14 except T1 and T2.

Application of N, P, K with micronutrients Fe and Zn are known to increase the uptake of Zn and Fe due to increased metabolic activities in plant.

Similar results reported as maximum total uptake of micronutrients (Fe, Mn, Zn and Cu) of paddy by separate foliar application of Fe-EDTA and Zn-EDTA than their combined application by Ram *et al.* (2013), Shivay *et al.* (2015), Verma and Tripathi (2010) and Sharma, *et al.* (1986).

**Table 12: Effect of different treatments on total uptake of micronutrients (Fe, Mn, Zn and Cu) by paddy.**

Treatment detail	Total uptake of micronutrients			
	Fe	Mn	Zn	Cu
	mg pot <sup>-1</sup>			
<b>T1:</b> Control	0.120	0.003	0.002	0.003
<b>T2:</b> GRDF	0.244	0.012	0.003	0.006
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	0.404	0.010	0.005	0.008
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	0.496	0.012	0.007	0.008
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	0.291	0.010	0.008	0.010
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	0.305	0.009	0.010	0.008
<b>T7:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.1%	0.357	0.011	0.007	0.009
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	0.482	0.006	0.009	0.008
<b>T9:</b> GRDF + Fe @ 0.1%	0.356	0.012	0.005	0.011
<b>T10:</b> GRDF + Zn @ 0.1%	0.277	0.008	0.007	0.008
<b>T11:</b> GRDF + Fe @ 0.5%	0.431	0.008	0.005	0.011
<b>T12:</b> GRDF + Zn @ 0.5%	0.319	0.008	0.009	0.009
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	0.353	0.013	0.006	0.011
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	0.413	0.013	0.008	0.011
<b>SE ±</b>	0.007	0.001	0.0003	0.001
<b>CD (P=0.05)</b>	0.020	0.004	0.0008	0.004

#### **4.6 Effect of different treatments on chemical properties of soil.**

The data in respect of effect of foliar application of iron and zinc on chemical properties of soil as pH, EC, organic carbon and calcium carbonate is presented in Table 13 and on available N, P, K and available micronutrients (Fe, Mn, Zn and Cu) is presented in Table 14 and 15 respectively.

The data revealed that the pH, EC, organic carbon and calcium carbonate of soil after harvest of paddy were not affected significantly due to foliar application of iron and zinc.

Also the available N, P, K and available micronutrients (Fe, Mn, Zn and Cu) of soil after harvest of paddy were not affected significantly due to foliar application of iron and zinc. Similar results i.e. chemical properties of soil were not affected significantly due to foliar application of iron and zinc were reported by Keram *et al.* (2012) and Radhika *et al.* (2013).

**Table 13: Effect of different treatments on chemical properties of soil after harvest.**

<b>Treatment detail</b>	<b>pH (1:2.5)</b>	<b>EC (dSm<sup>-1</sup>)</b>	<b>Organic carbon (%)</b>	<b>Per cent CaCO<sub>3</sub> equivalent</b>
<b>T1:</b> Control	7.6	0.26	0.65	5.23
<b>T2:</b> GRDF	7.6	0.25	0.66	5.30
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	7.6	0.27	0.66	5.30
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	7.7	0.25	0.66	5.40
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	7.4	0.30	0.67	5.40
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	7.7	0.25	0.67	5.60
<b>T7:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.1%	7.7	0.24	0.66	5.40
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	7.6	0.31	0.67	5.60
<b>T9:</b> GRDF + Fe @ 0.1%	7.7	0.29	0.66	5.40
<b>T10:</b> GRDF + Zn @ 0.1%	7.6	0.26	0.67	5.50
<b>T11:</b> GRDF + Fe @ 0.5%	7.6	0.31	0.66	5.40
<b>T12:</b> GRDF + Zn @ 0.5%	7.7	0.26	0.67	5.30
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	7.6	0.31	0.66	5.40
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	7.4	0.29	0.66	5.40
<b>SE ±</b>	0.01	0.01	0.004	0.10
<b>CD (P=0.05)</b>	NS	NS	NS	NS

**Table 14: Effect of different treatments on available N, P and K after harvest in soil.**

Treatment detail	N	P	K
	kg ha <sup>-1</sup>		
<b>T1:</b> Control	236.24	18.51	138.8
<b>T2:</b> GRDF	239.38	19.41	147.8
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	241.47	19.41	134.4
<b>T4:</b> GRDF + Fe- EDTA @ 0.5%	233.11	19.41	134.4
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	232.06	18.81	138.8
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	236.24	19.11	138.8
<b>T7:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.1%	238.33	20.01	134.4
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	233.11	19.41	125.4
<b>T9:</b> GRDF + Fe @ 0.1%	236.24	19.41	138.8
<b>T10:</b> GRDF + Zn @ 0.1%	233.11	20.01	138.8
<b>T11:</b> GRDF + Fe @ 0.5%	235.20	19.71	143.28
<b>T12:</b> GRDF + Zn @ 0.5%	238.24	19.71	147.8
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	238.33	18.51	143.28
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	239.38	19.41	134.4
<b>SE ±</b>	2.45	0.80	6.84
<b>CD (P=0.05)</b>	NS	NS	NS

**Table 15: Effect of different treatments on available Micronutrients (Fe, Mn, Zn and Cu) after harvesting soil.**

Treatment detail	Micronutrient conc. in soil			
	Fe	Mn	Zn	Cu
	Mg pot <sup>-1</sup>			
<b>T1:</b> Control	3.95	2.63	0.58	0.21
<b>T2:</b> GRDF	3.97	2.66	0.57	0.23
<b>T3:</b> GRDF + Fe-EDTA @ 0.1%	3.96	2.63	0.58	0.22
<b>T4:</b> GRDF + Fe-EDTA @ 0.5%	4.00	2.65	0.57	0.22
<b>T5:</b> GRDF + Zn-EDTA @ 0.1%	4.02	2.65	0.58	0.23
<b>T6:</b> GRDF + Zn-EDTA @ 0.5%	4.28	2.64	0.57	0.22
<b>T7:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.1%	3.96	2.65	0.59	0.23
<b>T8:</b> GRDF + Fe-EDTA + Zn-EDTA each @ 0.5%	3.96	2.66	0.59	0.22
<b>T9:</b> GRDF + Fe @ 0.1%	4.03	2.65	0.57	0.22
<b>T10:</b> GRDF + Zn @ 0.1%	3.97	2.65	0.57	0.23
<b>T11:</b> GRDF + Fe @ 0.5%	3.95	2.65	0.58	0.22
<b>T12:</b> GRDF + Zn @ 0.5%	4.00	2.64	0.58	0.23
<b>T13:</b> GRDF + Fe + Zn each @ 0.1%	3.95	2.66	0.57	0.23
<b>T14:</b> GRDF + Fe + Zn each @ 0.5 %	3.99	2.65	0.58	0.22
<b>SE ±</b>	0.09	0.08	0.05	0.05
<b>CD (P=0.05)</b>	NS	NS	NS	NS

## 5. SUMMARY AND CONCLUSION

The present investigation entitled “Foliar application of iron and zinc on growth, yield and nutrient uptake of paddy” was undertaken during *kharif* season 2016-2017 in wire house of department of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur. The experiment was laid out in Completely Randomized Block Design with fourteen treatments and three replications. The important findings of the present investigation are summarized below:

1. Plant height and number of tillers increased significantly over control due to foliar application of Fe and Zn. The highest plant height (63.59 cm) and highest no. of tillers (25.66 pot<sup>-1</sup>) were recorded by foliar application of Fe-EDTA and Zn-EDTA each @ 0.5 % with GRDF.
2. The treatment T8 (Fe-EDTA and Zn-EDTA each @ 0.5 % foliar application with GRDF) recorded significantly superior grain and straw yield (35.54 and 39.01 g pot<sup>-1</sup> respectively) of paddy over all the treatments.
3. The N, P, K uptake was significantly increases due to foliar application of different sources and concentrations of Fe and Zn. The treatment T8 (Fe-EDTA and Zn-EDTA each @ 0.5 % foliar application with GRDF) recorded significantly highest uptake of N, P, K (588.50, 164.10 and 712.57 mg pot<sup>-1</sup> respectively) by paddy.
4. The micronutrients Fe, Mn, Zn, Cu uptake (0.496, 0.013, 0.010 and 0.011 mg pot<sup>-1</sup>) was significantly increased due to foliar application of different sources and concentrations of Fe and Zn with GRDF.

5. After harvest of crop, there was no significant difference in chemical properties of soil as pH, EC, organic carbon, calcium carbonate and available N, P, K and available micronutrients (Fe, Mn, Zn and Cu) in soil due to foliar spray of Fe and Zn with recommended dose of N, P, K.

### **CONCLUSIONS**

1. Plant height, number of tillers, grain and stover yield (63.59, 25.66, 35.54 and 39.01 respectively) per pot of paddy was significantly increased due to the combined foliar application of Fe-EDTA and Zn-EDTA @ 0.5% with GRDF at tillering and panicle stage over all the treatments.
2. The foliar application of Fe-EDTA + Zn-EDTA @ 0.5% with GRDF significantly increased the total uptake of N, P, K, Fe, Mn, Zn and Cu. However the chemical properties and availability of nutrients in soil after harvest were found non-significant.

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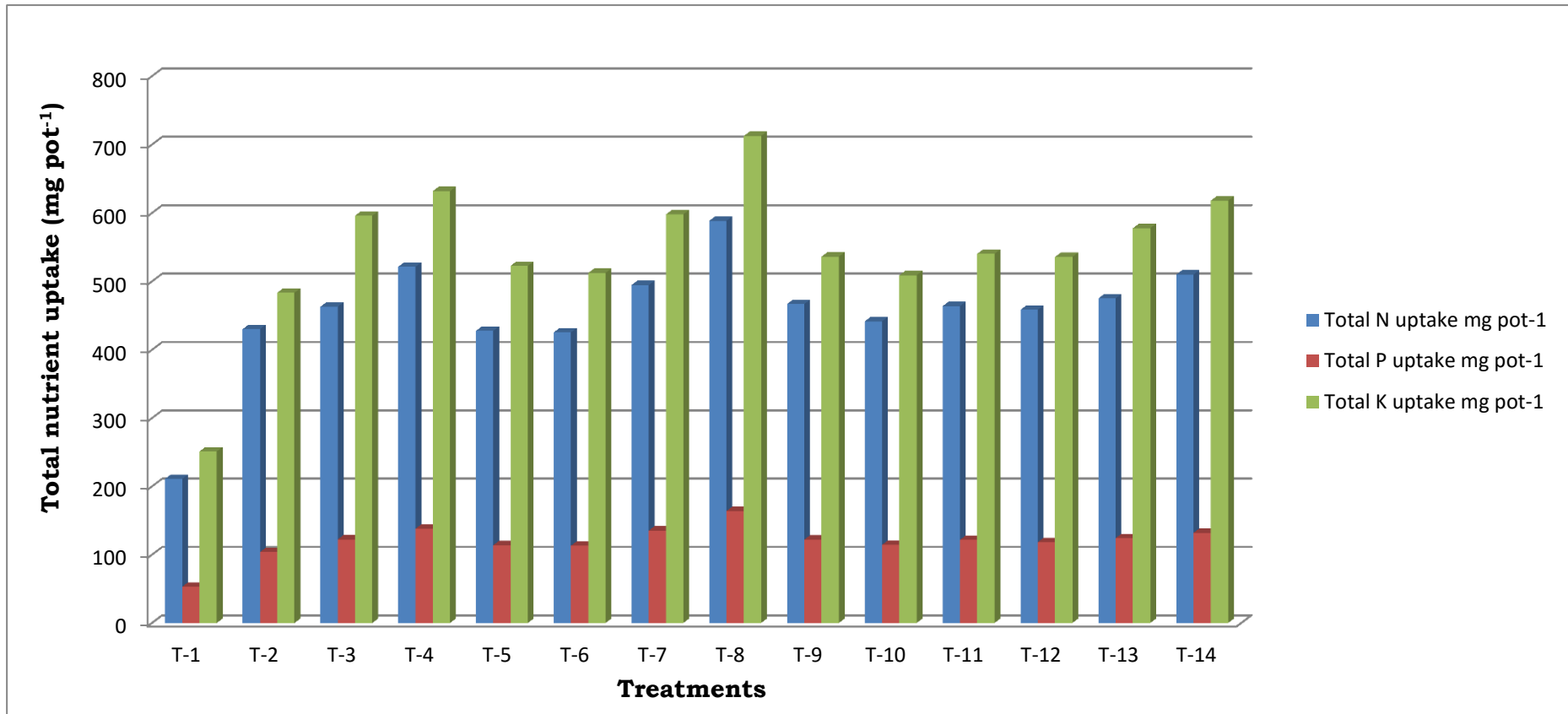
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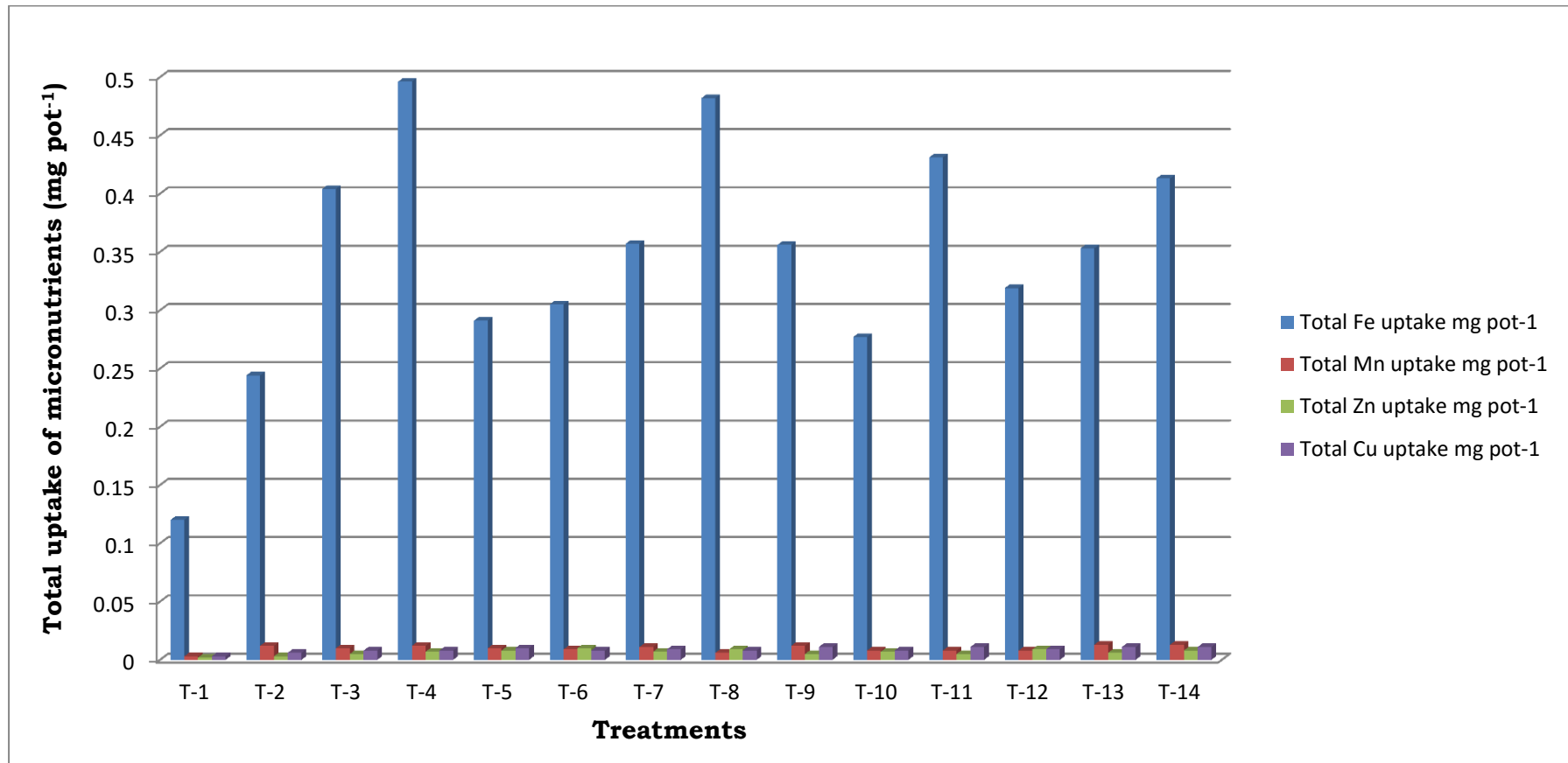
**MISS. DHINDALE MADHURI SURESH**  
**A candidate for the degree**  
**Of**  
**MASTER OF SCIENCE (AGRICULTURE)**  
**in**  
**SOIL SCIENCE AND AGRICULTURE CHEMISTRY**  
**2017**

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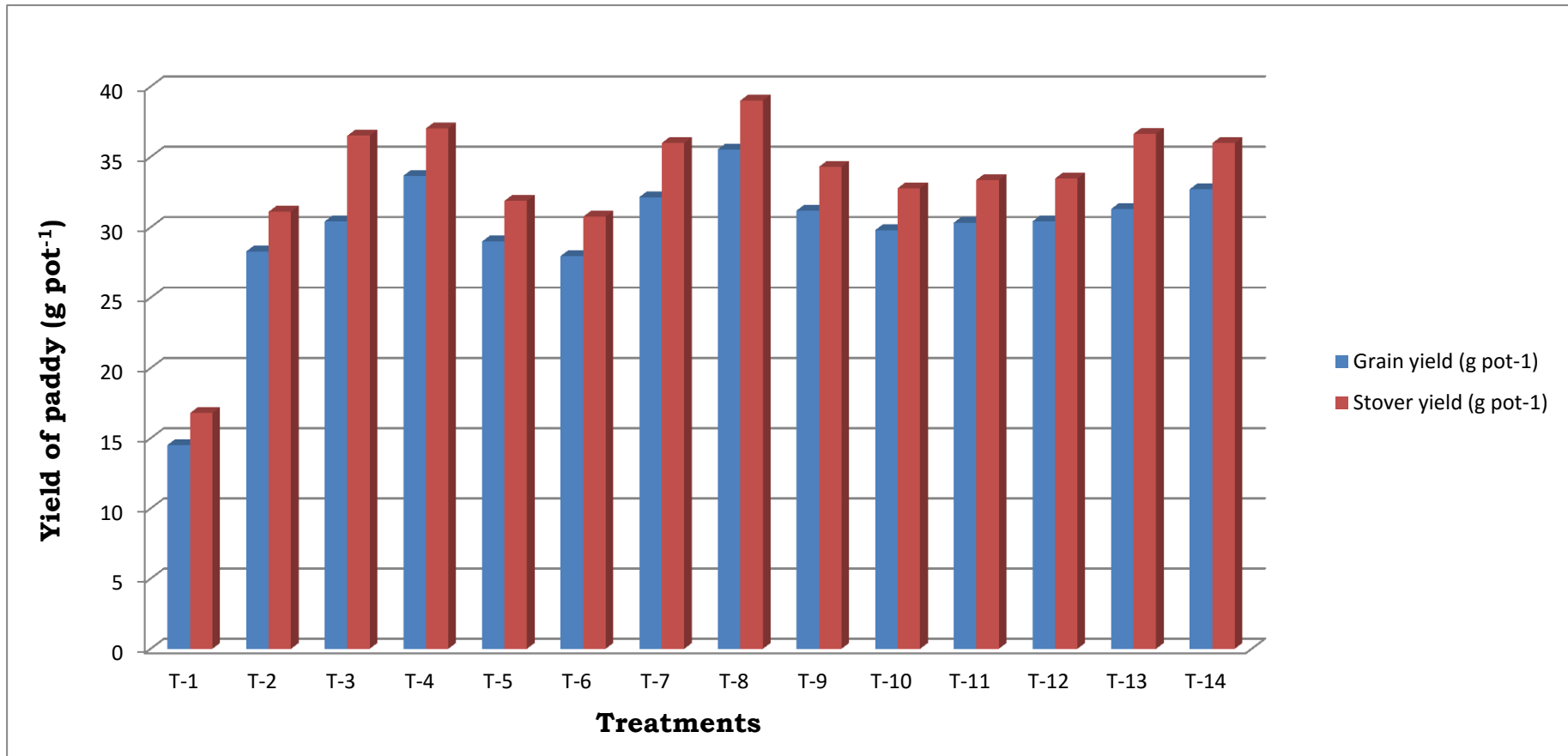
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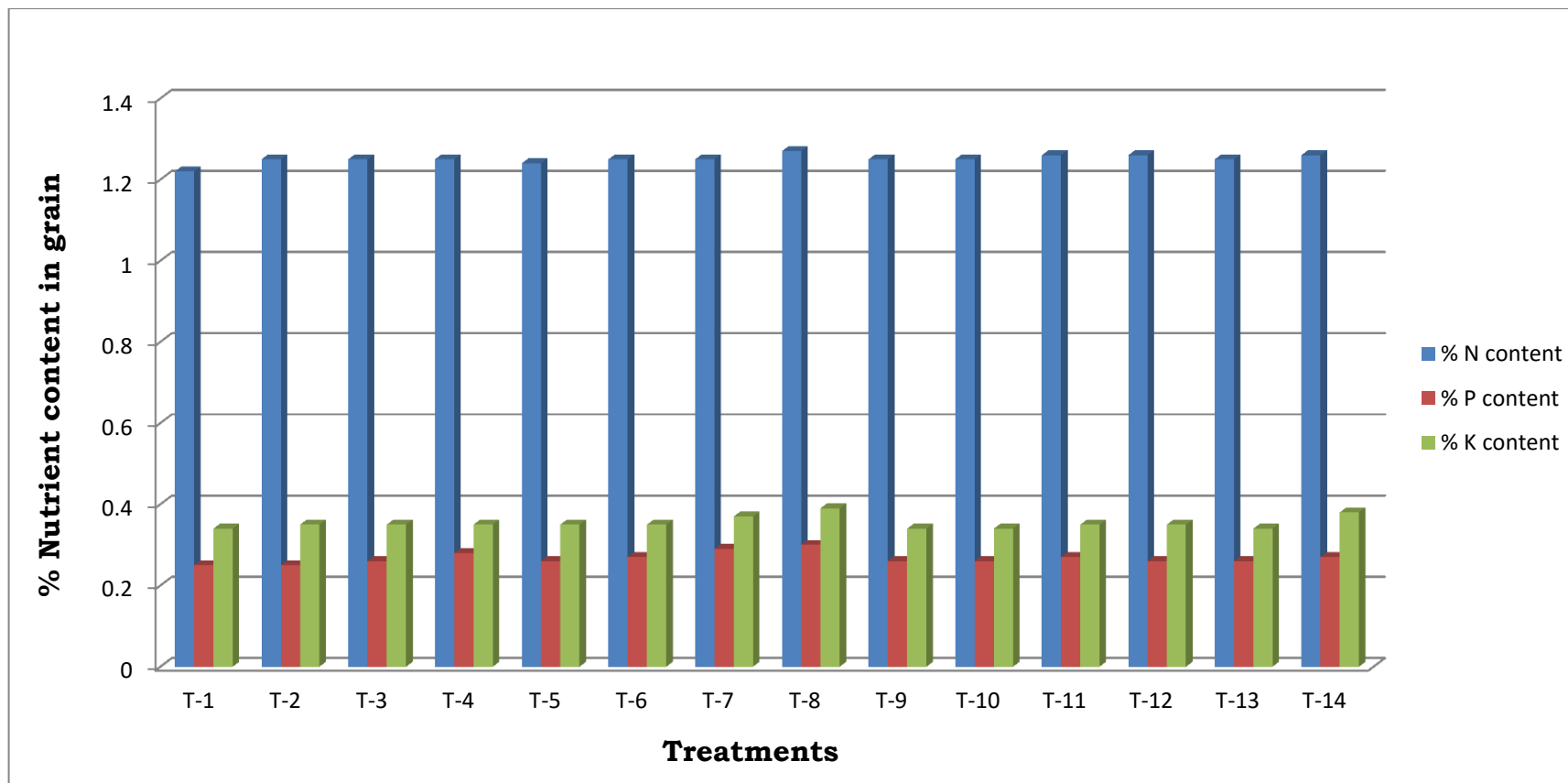
**Fig 4. Effect of different treatments on total uptake of N, P and K by paddy at harvest**



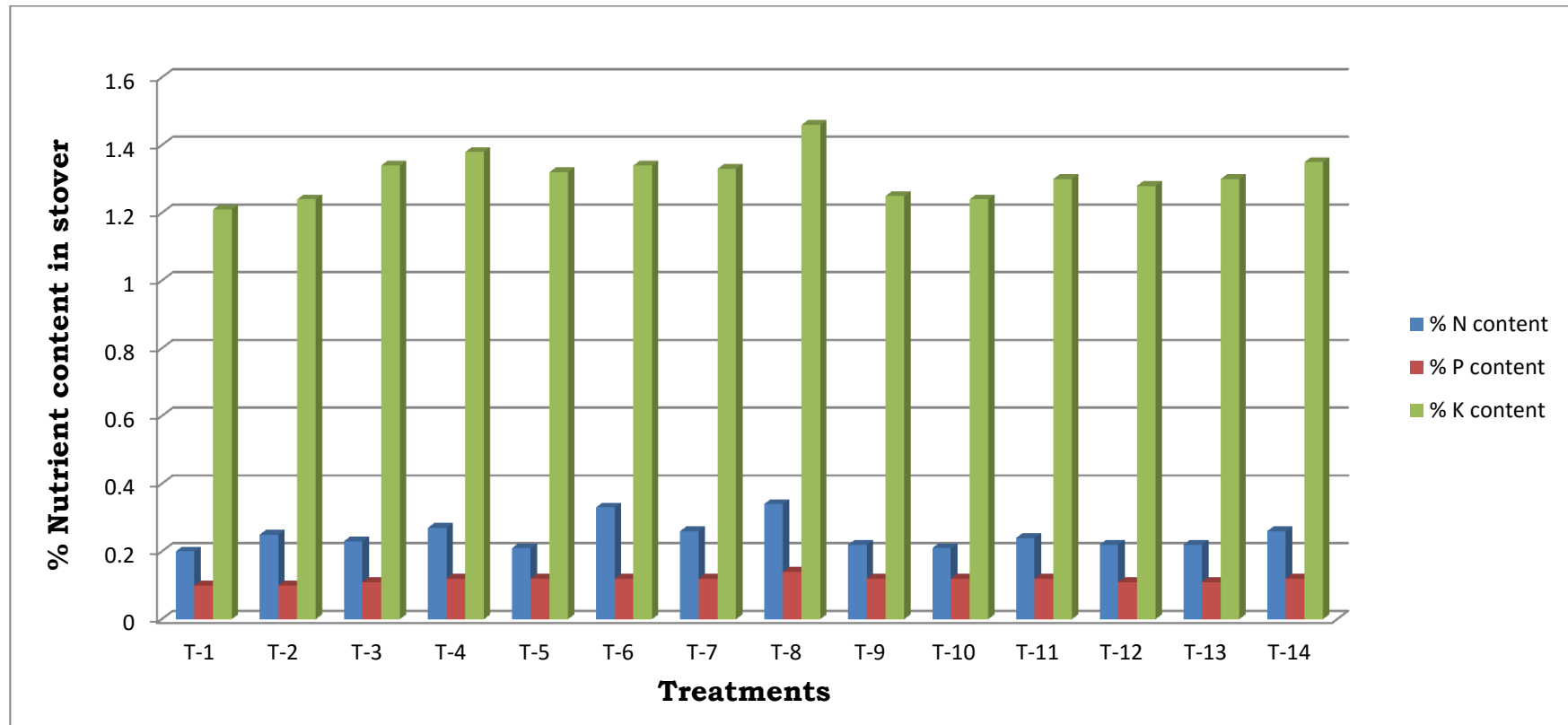
**Fig 7. Effect of different treatments on total uptake of micronutrients (Fe, Mn, Zn and Cu) by paddy at harvest.**



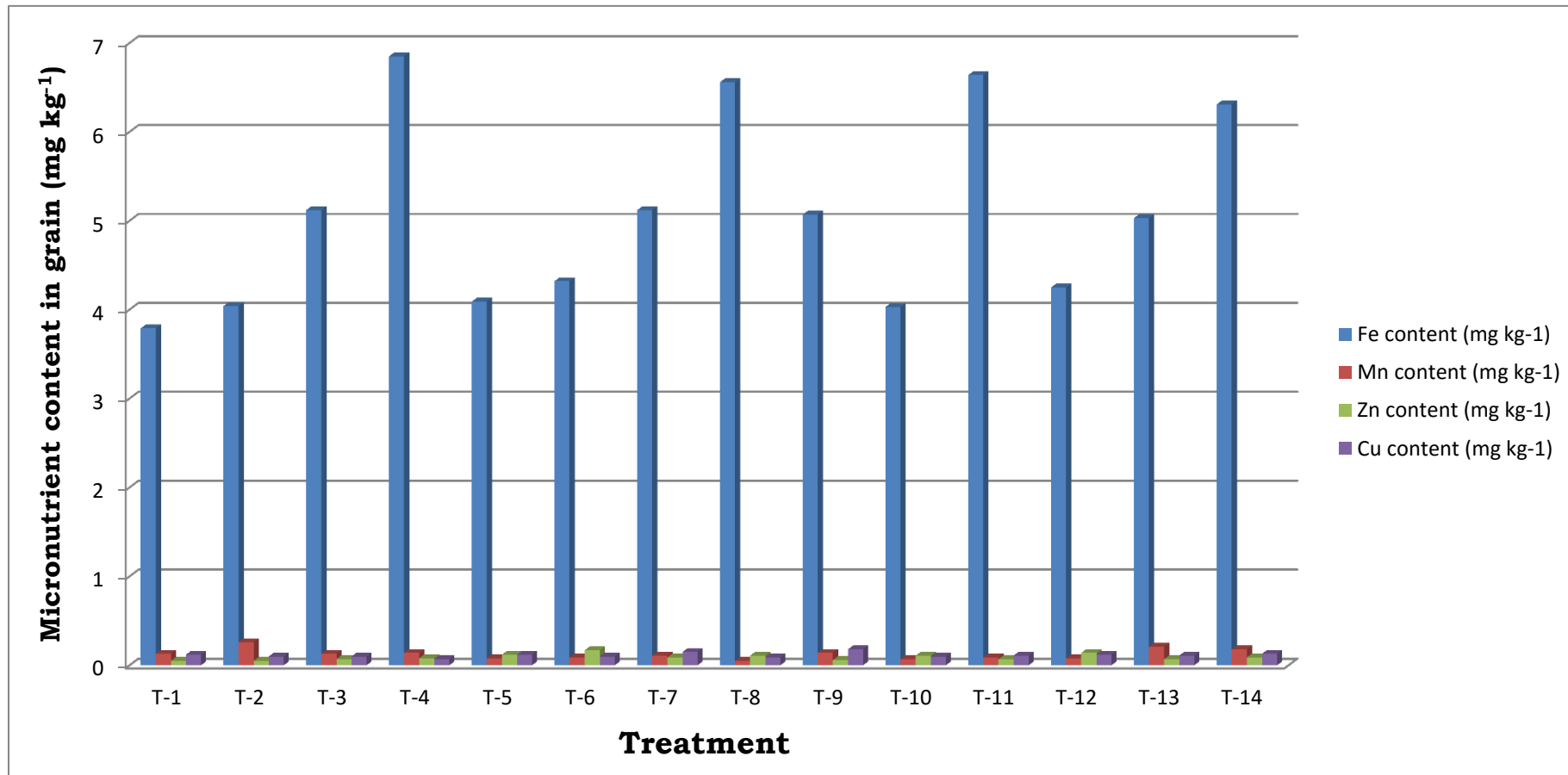
**Fig 1. Effect of different treatments on grain and stover yield of paddy.**



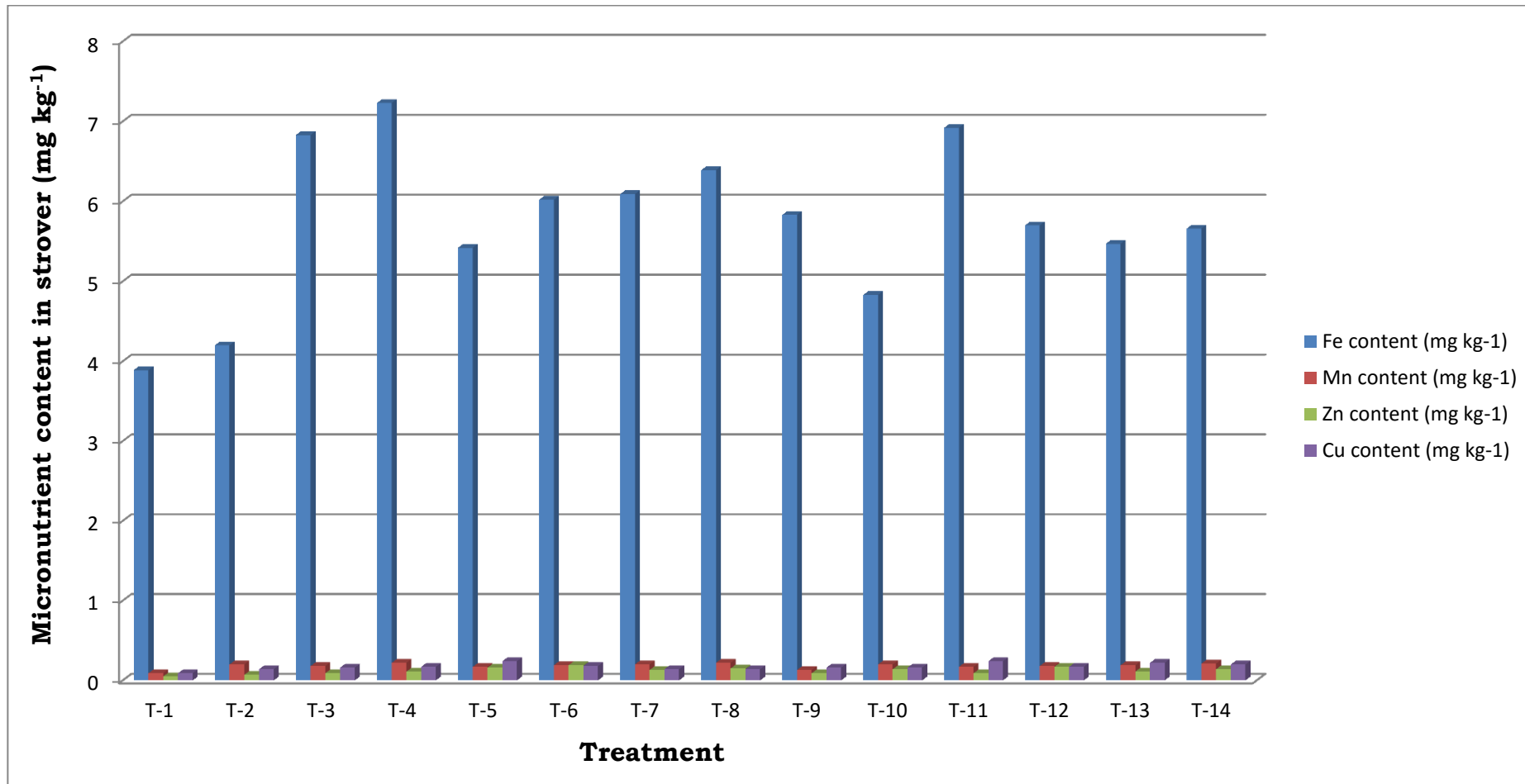
**Fig 2. Effect of different treatments on per cent nutrient (N, P and K) content in grain of paddy**



**Fig 3. Effect of different treatments on per cent nutrient (N, P and K) content in stover of paddy.**



**Fig 5. Effect of different treatments on micronutrient (Fe, Mn, Zn and Cu) content in grain of paddy.**



**Fig 6. Effect of different treatments on micronutrient (Fe, Mn, Zn and Cu) content in stover of paddy.**