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## Effect of zinc fertilization on growth, yield and micronutrients content and uptake by paddy

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**Abstract**

Experimentation at twenty farmer's field of tribal area of Mandla district of Madhya Pradesh during Kharif 2015-16 considering zinc variability in soil as low, medium and high, and Zn levels through  $ZnSO_4 \cdot 7H_2O$  in a RBD. The soils of selected sites were clayey, alkaline in pH, organic carbon varied from less to marginal and varied in available Zn from 0.12 to 2.17 mg kg<sup>-1</sup>. The rice MTU-1010 seed was sown @ 80 kg ha<sup>-1</sup> with recommended practices and harvested at maturity (120 DAS).

Significant effects were noted on growth and yield components yield content and uptake by rice: plant height in S-12 (36.73 cm), no. of tillers/ hill (9.79) in S-17, no. grains/panicle varied from 53.00 (S-6) and to 71.33 (S-7) and test weight (24.25 g) in soil S-7. Yield was recorded S-9 (4.75 t/ha) which was at par with S-14 (4.47 t ha<sup>-1</sup>). Highest tillers per hill<sup>-1</sup> (8.15) were noted with basal application @ 8 kg Zn ha<sup>-1</sup> but similar with (8.03) just 6 kg and low with no zinc. It had also increased the yield (3.57 t ha<sup>-1</sup>) but at par with 6.0 kg Zn ha<sup>-1</sup> (3.44 t ha<sup>-1</sup>). Zinc content and its uptake varied and recorded more in 8.0 kg Zn ha<sup>-1</sup> but equal to 6 kg Zn ha<sup>-1</sup>.

**Keywords:** Uptake, yield, MTU 1010, rice, zinc fertilization

**Introduction**

Rice (*Oryza sativa* L.) is important cereal crops grown on tribal areas of Mandla district of Madhya Pradesh. In India, it is grown over 43.86 million ha and producing 104.80 mt with productivity of 2.42 tonnes ha<sup>-1</sup> which was far below than other country (4.09 t ha<sup>-1</sup>). In the state, it is grown on 2.15 mha with production of 3.63 mt and productivity of 1.44 t ha<sup>-1</sup>. The productivity gap between national and state level is very wide. Blanket application of Zinc fertilizers by the farmers in fields might cause adverse effect on soils and crops.

Zinc is involved in physiological functions and its inadequate supply reduces the yield of crop. Its deficiencies can affect quality of produces. It is a constituent of many enzymes and role in carbohydrate and protein synthesis, maintaining the integrity of membranes, regulating auxin synthesis and in pollen formation. Its deficiency is a common problem in food crops, causing reduction in yield and quality of produces. In India analysis of 14,863 soil samples showed that 49% of soils are deficient and in Madhya Pradesh 60.3% of 6713 soil samples analyzed indicated deficiency of Zn (Shukla & Tiwari *et al.*, 2014) [2]. In this situation the crops cultivated have low yield and produce seeds without Zn content.

Zinc plays significant role in rice production but its deficiency is widespread and continues to be a limiting factor (Yilmaz *et al.*, 2010) [3]. Zinc sulphate is used in the amelioration of Zn deficiency and in the enrichments of grains (Alloway, 2009) [4]. Zn influences growth, yield and quality of paddy (Patnaik *et al.*, 2011) [5]. Under low zinc status the crops are responded by 56.6% and 13.8%, with 10 mg kg<sup>-1</sup> zinc addition by increased significantly the yield of rice grain and straw, respectively. Whereas 28.5% and 9.6% response was observed in zinc sufficient soils (Sharma *et al.*, 1995) [6]. Keeping in view the important role of cereal in the economy of the tribals but limited information about this nutrient in soil, there is an urgent need for an accurate estimation of Zn in soils of central India.

**Material and Methods****Description of location**

Mandla district cover an area of 8771 km<sup>2</sup> between the latitudes 22° 02'' and 23° 22' N and longitudes 80° 18' and 81° 50' East, the district is of 443 to 1100 meters from the MSL.

The main crops are Maize, Kodo, Kutki, Paddy, Ramtil, Arhar, and Soybean. The mean rain fall of 1250-1427.7 mm and feels max temp up to 41.3°C and min up to 22°C in *Kharif* season.

### Experimental details

Field experiments were conducted during *Kharif* 2015-16 at twenty farmer's field on Typic Haplusterts of Mandla district of Madhya Pradesh. The soils are clayey, alkaline in nature and low to marginal in OC. The Zn treatments were applied at basal 60 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O were applied through urea, SSP and MOP respectively. and 60 kg N ha<sup>-1</sup> was applied at tillering stage. The rice MTU-1010 seed was sown @ 80 kg ha<sup>-1</sup>. From each experimental site, soil (0-15 cm depth) samples were collected before and after harvest of rice crop. The samples were air dried and sieved through 2 mm sieve. 1 g of seed/ stover and add diacid mixture of HNO<sub>3</sub> and HClO<sub>4</sub> (10:4) was digested. The digestate was transferred in 50 ml to the mark with distilled water. The crude protein content (%) worked out by multiplying N content with factor 6.25. Zn content was determined by AAS.

### Result and Discussion

#### Yield components:

Data showed (Table-1) that the plant height was recorded more in S-12 at harvest (36.73 cm). Soil S-17 recorded more of tillers/ hill (9.80). The no. of grains panicle<sup>-1</sup> varied from 53.00 (S-6) and to 71.33 (S-7). The test weight was observed in soil S-7(24.25 g) which at par with soil S-5 (23.94 g). These results might be due to variability of Zn in soils deficient marginal and high. The result has been also reported by Sharma *et al.* (1995)<sup>[6]</sup> and Bajpai *et al.* (2016)<sup>[7]</sup>.

The plants fertilized with 8.0 kg Zn ha<sup>-1</sup> produced more number of tillers and grains panicle<sup>-1</sup> as compared to other treatments. Significantly test weight was recorded with 8.0 kg Zn ha<sup>-1</sup> (23.36 g) and it was at par with 4 & 8 kg Zn ha<sup>-1</sup>. However, it was statistically similar to just lower dose of Zn. The results might be due to the adequate supply Zn which accelerates the enzymatic activity and auxin metabolism in plants Chand *et al.* (2016)<sup>[8]</sup>.

#### Yield

Highest grain yield was recorded S-9 (4.75 t ha<sup>-1</sup>) and at par with S-14 (4.47 t ha<sup>-1</sup>). The S-14 registered highest straw yield (9.39 tha<sup>-1</sup>) and it was statistically at par with S-13 (9.36 t ha<sup>-1</sup>). The lowest grain and straw yield were recorded in soil S-2. Highest grain (3.75 t ha<sup>-1</sup>) and straw (7.69 t ha<sup>-1</sup>) yield with 8.0 kg Zn ha<sup>-1</sup> and it was at par with just lower dose of Zn. Minimum grain yield (2.51 t ha<sup>-1</sup>) and yield of straw (5.63 t ha<sup>-1</sup>) were obtained from no zinc. Interaction effect of was non-significant. The highest grain yield was recorded S-9 (4.75 t ha<sup>-1</sup>) which was equal with S-14 (4.47 t ha<sup>-1</sup>). The results might be attributed to the adequate supply Zn which proliferation of roots and thereby increased the uptake, supplying it to the aerial parts and ultimately enhancing growth and yield. The finding was supported by Muthukumararaja and Sriramachandrasekharan (2012)<sup>[10]</sup> Khan *et al.* (2005), Yadav *et al.* (2013)<sup>[13]</sup> and Prasad *et al.* (2014).

### Protein content

The highest protein (8.61%) was observed in soil S-4. The minimum protein was recorded under S-2. Zinc fertilization, observed the highest protein % with of 8.0 kg Zn ha<sup>-1</sup> (7.75%) and at par with 6.0 kg Zn ha<sup>-1</sup>. Similar results have been reported by Dubey *et al.*, (2016)<sup>[11]</sup>.

### Micronutrient content

Interaction effect was non-significant. The highest zinc content in grain and straw was recorded under S-2 (17.31 mg kg<sup>-1</sup>) and S-15 (26.75 mg kg<sup>-1</sup>), respectively. The highest Cu content in grain and straw was recorded under soil S-18 (5.18 mg kg<sup>-1</sup>) and S-19 (7.49 mg kg<sup>-1</sup>), respectively. The highest Fe content in grain was recorded soil S-4 (73.95 mg kg<sup>-1</sup>). However, it was statistically at par with S-5 (73.46 mg kg<sup>-1</sup>). The Fe content in straw was highest under S-15 (236.27 mg kg<sup>-1</sup>). The highest Mn content in grain was recorded S-9 (58.27 mg kg<sup>-1</sup>). However it was highest under S-17 (26.53 mg kg<sup>-1</sup>) in case of straw.

The highest zinc content in grain and straw was recorded with 8.0 kg Zn ha<sup>-1</sup> (14.36 and 22.57 mg kg<sup>-1</sup>) as compared to others and at par with 4 and 6.kg Zn ha<sup>-1</sup>. The highest Cu content in grain and straw was recorded with 8.0 kg Zn ha<sup>-1</sup>, (4.03 and 5.88 mg kg<sup>-1</sup>) and similar with other levels except control. The highest Fe content in grain and straw was recorded with 8.0 kg Zn ha<sup>-1</sup> (53.33 and 178.41 mg kg<sup>-1</sup>) and at par with 4 and 6.kg Zn ha<sup>-1</sup>. The highest Mn content in grain 44.11 and straw 216.73 mg kg<sup>-1</sup> was recorded with 8.0 kg Zn ha<sup>-1</sup> as compared to others. However, it was statistically equal with 2, 4 and 6.0 kg Zn ha<sup>-1</sup> in respect of grain. The results are supported by Pandey *et al.* (2012)<sup>[12]</sup>.

### Micro nutrient uptake by rice

Interaction effect due to different status of Zn in soils and zinc fertilization was non-significant. The highest and lowest uptake by grain were recorded under S-9 (68.15 g ha<sup>-1</sup> and S-6 (30.04 g ha<sup>-1</sup>), respectively. However, high and low uptake by straw and its total were observed under S-14 and S-2 (247.78 and 309.89 g ha<sup>-1</sup> and 118.55 and 155.27 g ha<sup>-1</sup>), respectively. The highest Cu uptake by grain was recorded under S-9 (21.45 g ha<sup>-1</sup>) and minimum Cu uptake by grain under S-20 (7.99 g ha<sup>-1</sup>). However, highest and lowest Cu uptake by straw 68.54 g ha<sup>-1</sup> and total Cu uptake 19.40 was recorded under S-14 and S-8 (27.77 and 52.26 g ha<sup>-1</sup>), respectively. The highest Fe uptake by grain, straw and total Fe uptake was recorded under S-9 (272.50, 1881.94 and 2154.43 g ha<sup>-1</sup>), respectively. The highest Mn uptake by grain, straw and total was calculated under S-9 (296.86, 2120.28 and 2417.14 g ha<sup>-1</sup>), respectively. The finding was corroborated with Shehu *et al.* (2010)<sup>[13]</sup> and Mhoro *et al.* (2015)<sup>[14]</sup>.

The plants fertilized with 8.0 kg Zn ha<sup>-1</sup> recorded more Zn, Cu, Fe and Mn uptake by grain straw and total Zn uptake as compared to other zinc fertilization but equal with 6.0 kg Zn ha<sup>-1</sup>. The lowest zinc uptake by grain straw and its total was observed under no zinc. Interaction effect due to different status of Zn in soils and zinc fertilization was non-significant. The above findings are in agreement with reported by Mhoro *et al.* (2015)<sup>[14]</sup>.

**Table 1:** Effect of Zn application on growth, yield components and yield

| Treatment                        | Yield parameters |                  |                |                             | Yield(t ha <sup>-1</sup> ) |       | Protein (%) |
|----------------------------------|------------------|------------------|----------------|-----------------------------|----------------------------|-------|-------------|
|                                  | Soils            | Plant height(cm) | No. of tillers | Grain panicle <sup>-1</sup> | Test weight(g)             | Grain |             |
| S-1                              | 31.13            | 5.27             | 63.73          | 23.42                       | 2.57                       | 6.68  | 7.24        |
| S-2                              | 31.00            | 5.73             | 66.53          | 23.23                       | 2.12                       | 4.67  | 6.86        |
| S-3                              | 32.20            | 6.13             | 64.33          | 22.84                       | 2.77                       | 5.49  | 8.12        |
| S-4                              | 32.73            | 6.13             | 57.60          | 22.45                       | 3.06                       | 6.46  | 8.61        |
| S-5                              | 29.33            | 6.47             | 63.40          | 23.94                       | 2.91                       | 5.51  | 8.18        |
| S-6                              | 31.27            | 5.53             | 53.00          | 22.02                       | 2.48                       | 6.55  | 8.13        |
| S-7                              | 32.00            | 7.80             | 71.33          | 24.25                       | 2.88                       | 7.73  | 6.88        |
| S-8                              | 31.73            | 6.53             | 64.20          | 20.33                       | 2.54                       | 5.67  | 8.30        |
| S-9                              | 34.93            | 6.47             | 60.07          | 21.02                       | 4.75                       | 8.71  | 7.60        |
| S-10                             | 31.67            | 7.27             | 61.13          | 22.48                       | 4.15                       | 6.80  | 7.11        |
| S-11                             | 32.93            | 8.40             | 61.67          | 21.45                       | 2.75                       | 8.00  | 7.22        |
| S-12                             | 36.73            | 9.67             | 64.33          | 22.75                       | 3.15                       | 8.48  | 7.23        |
| S-13                             | 33.33            | 8.07             | 67.53          | 22.09                       | 3.61                       | 9.36  | 8.41        |
| S-14                             | 36.07            | 6.13             | 57.73          | 21.58                       | 4.47                       | 9.39  | 7.82        |
| S-15                             | 30.40            | 8.67             | 65.93          | 22.29                       | 3.42                       | 5.65  | 7.62        |
| S-16                             | 36.67            | 7.40             | 62.80          | 22.76                       | 3.38                       | 6.30  | 7.67        |
| S-17                             | 32.33            | 9.80             | 68.47          | 22.61                       | 2.27                       | 5.80  | 7.52        |
| S-18                             | 33.13            | 8.20             | 61.47          | 23.73                       | 2.97                       | 5.84  | 8.56        |
| S-19                             | 30.93            | 9.33             | 64.53          | 22.58                       | 2.84                       | 6.14  | 8.32        |
| S-20                             | 30.13            | 8.00             | 63.13          | 23.33                       | 3.24                       | 6.00  | 7.76        |
| SEM                              | 0.889            | 0.483            | 1.709          | 0.773                       | 0.147                      | 0.236 | 0.121       |
| LSD ( <i>P</i> <0.05)            | 1.796            | 0.975            | 3.454          | 1.562                       | 0.297                      | 0.478 | 0.245       |
| Zn Levels (kg ha <sup>-1</sup> ) |                  |                  |                |                             |                            |       |             |
| 0                                | 30.17            | 6.50             | 62.73          | 21.17                       | 2.51                       | 5.63  | 7.23        |
| 2                                | 31.18            | 6.97             | 61.85          | 21.97                       | 2.87                       | 6.21  | 7.38        |
| 4                                | 33.03            | 7.60             | 63.28          | 22.65                       | 3.23                       | 6.82  | 7.58        |
| 6                                | 34.00            | 8.03             | 64.03          | 23.21                       | 3.44                       | 7.46  | 7.65        |
| 8                                | 34.28            | 8.15             | 63.83          | 23.36                       | 3.57                       | 7.69  | 7.75        |
| SEM                              | 0.444            | 0.241            | 0.854          | 0.387                       | 0.074                      | 0.118 | 0.061       |
| LSD ( <i>P</i> <0.05)            | 0.898            | 0.488            | 1.727          | 0.781                       | 0.149                      | 0.239 | 0.122       |
| Interaction                      |                  |                  |                |                             |                            |       |             |
| SEM                              | 1.987            | 1.079            | 3.821          | 1.729                       | 0.329                      | 0.529 | 0.271       |
| LSD ( <i>P</i> <0.05)            | Non-Significant  |                  |                |                             |                            |       |             |

**Table 2:** Influence of Zn application on concentration of micronutrients (mg kg<sup>-1</sup>) in rice

| Treat.                          | Zn    |       | Cu    |       | Fe    |        | Mn    |        |
|---------------------------------|-------|-------|-------|-------|-------|--------|-------|--------|
|                                 | Grain | Straw | Grain | Straw | Grain | Straw  | Grain | Straw  |
| S-1                             | 15.85 | 23.30 | 3.38  | 6.42  | 64.75 | 124.69 | 50.07 | 142.80 |
| S-2                             | 17.31 | 25.32 | 4.35  | 4.82  | 58.76 | 109.90 | 56.07 | 202.45 |
| S-3                             | 15.90 | 21.02 | 4.53  | 7.24  | 69.76 | 155.44 | 41.20 | 214.28 |
| S-4                             | 15.65 | 20.09 | 3.61  | 4.53  | 73.95 | 197.59 | 40.51 | 222.50 |
| S-5                             | 15.24 | 21.46 | 3.74  | 5.28  | 73.46 | 213.76 | 33.22 | 258.45 |
| S-6                             | 12.09 | 22.08 | 3.37  | 6.82  | 44.81 | 218.00 | 42.89 | 238.27 |
| S-7                             | 12.12 | 18.88 | 3.39  | 4.51  | 39.08 | 149.04 | 41.61 | 152.70 |
| S-8                             | 12.04 | 19.32 | 3.26  | 3.41  | 43.79 | 137.39 | 36.83 | 237.10 |
| S-9                             | 14.27 | 20.12 | 4.51  | 4.80  | 57.21 | 215.44 | 58.27 | 243.45 |
| S-10                            | 14.04 | 22.67 | 4.32  | 7.24  | 34.69 | 216.19 | 31.65 | 130.52 |
| S-11                            | 14.52 | 22.00 | 4.53  | 5.53  | 56.59 | 221.76 | 56.21 | 247.80 |
| S-12                            | 13.31 | 23.96 | 4.43  | 4.63  | 45.91 | 205.19 | 55.81 | 224.07 |
| S-13                            | 12.09 | 17.63 | 3.27  | 5.29  | 43.34 | 146.47 | 35.39 | 162.35 |
| S-14                            | 13.72 | 26.39 | 3.61  | 5.55  | 50.82 | 133.47 | 31.64 | 165.90 |
| S-15                            | 13.18 | 26.75 | 4.36  | 6.77  | 63.34 | 236.27 | 33.23 | 240.67 |
| S-16                            | 12.63 | 23.22 | 3.85  | 4.61  | 66.33 | 150.56 | 39.71 | 157.48 |
| S-17                            | 13.37 | 22.03 | 4.45  | 5.52  | 38.55 | 195.51 | 51.38 | 266.53 |
| S-18                            | 13.14 | 26.64 | 5.18  | 6.55  | 43.48 | 145.04 | 52.18 | 246.53 |
| S-19                            | 12.15 | 19.49 | 3.56  | 7.49  | 34.16 | 121.71 | 30.36 | 151.75 |
| S-20                            | 12.59 | 20.11 | 2.44  | 6.45  | 36.76 | 127.65 | 29.73 | 130.13 |
| SEM                             | 0.466 | 0.762 | 0.157 | 0.175 | 1.675 | 6.551  | 1.521 | 5.583  |
| LSD ( <i>P</i> <0.05)           | 0.942 | 1.541 | 0.318 | 0.353 | 3.385 | 13.240 | 3.075 | 11.282 |
| Zn Level (kg ha <sup>-1</sup> ) |       |       |       |       |       |        |       |        |
| 0                               | 12.49 | 20.53 | 3.63  | 5.24  | 48.52 | 155.26 | 39.58 | 180.80 |
| 2                               | 13.53 | 21.26 | 3.94  | 5.73  | 51.45 | 171.08 | 42.59 | 194.31 |
| 4                               | 13.96 | 22.02 | 3.93  | 5.71  | 53.26 | 172.68 | 42.78 | 207.92 |
| 6                               | 14.29 | 22.47 | 3.99  | 5.78  | 53.32 | 177.81 | 43.94 | 214.27 |
| 8                               | 14.36 | 22.57 | 4.03  | 5.88  | 53.32 | 178.40 | 44.10 | 216.62 |

|                  |                 |       |       |       |       |        |       |        |
|------------------|-----------------|-------|-------|-------|-------|--------|-------|--------|
| SEM              | 0.233           | 0.381 | 0.079 | 0.087 | 0.838 | 3.276  | 0.761 | 2.791  |
| LSD ( $P<0.05$ ) | 0.471           | 0.770 | 0.159 | 0.177 | 1.693 | 6.620  | 1.537 | 5.641  |
| Interaction      |                 |       |       |       |       |        |       |        |
| SEM              | 1.042           | 1.705 | 0.352 | 0.391 | 3.745 | 14.649 | 3.402 | 12.483 |
| LSD ( $P<0.05$ ) | Non-Significant |       |       |       |       |        |       |        |

**Table 3:** Effect of Zn application on micronutrients uptake ( $\text{g ha}^{-1}$ ) by rice

| Treat.   | Zn              |        |        | Cu    |       |       | Fe     |         |         | Mn     |         |         |
|--|-----------------|--------|--------|-------|-------|-------|--------|---------|---------|--------|---------|---------|
|  | Grain           | Straw  | Total  | Grain | Straw | Total | Grain  | Straw   | Total   | Grain  | Straw   | Total   |
| S-1  | 40.98           | 156.58 | 197.56 | 8.73  | 42.91 | 51.64 | 166.74 | 838.14  | 1004.88 | 129.57 | 959.77  | 1089.35 |
| S-2  | 36.71           | 118.55 | 155.27 | 9.24  | 22.87 | 32.11 | 124.99 | 518.18  | 643.17  | 118.79 | 961.82  | 1080.61 |
| S-3  | 44.38           | 115.71 | 160.09 | 12.71 | 39.91 | 52.62 | 193.79 | 856.78  | 1050.57 | 115.92 | 1187.47 | 1303.38 |
| S-4  | 48.14           | 131.21 | 179.35 | 11.09 | 29.22 | 40.32 | 226.45 | 1277.36 | 1503.80 | 124.55 | 1445.02 | 1569.57 |
| S-5  | 44.54           | 118.53 | 163.07 | 10.90 | 29.18 | 40.08 | 213.94 | 1184.61 | 1398.54 | 97.86  | 1484.33 | 1582.19 |
| S-6  | 30.04           | 145.01 | 175.05 | 8.34  | 44.89 | 53.23 | 111.46 | 1429.45 | 1540.92 | 106.58 | 1573.61 | 1680.18 |
| S-7  | 35.38           | 147.00 | 182.37 | 9.84  | 34.82 | 44.66 | 113.91 | 1162.19 | 1276.10 | 119.99 | 1187.31 | 1307.30 |
| S-8  | 30.85           | 110.63 | 141.48 | 8.31  | 19.46 | 27.77 | 111.14 | 780.06  | 891.20  | 94.54  | 1356.56 | 1451.11 |
| S-9  | 68.15           | 175.66 | 243.81 | 21.45 | 41.95 | 63.40 | 272.50 | 1881.94 | 2154.43 | 296.86 | 2120.28 | 2417.14 |
| S-10   | 58.86           | 154.80 | 213.66 | 18.17 | 49.42 | 67.59 | 145.15 | 1478.22 | 1623.38 | 131.16 | 904.50  | 1035.66 |
| S-11   | 40.07           | 176.16 | 216.23 | 12.51 | 44.30 | 56.80 | 156.05 | 1783.27 | 1939.32 | 154.77 | 1992.97 | 2147.74 |
| S-12   | 41.96           | 203.91 | 245.87 | 13.91 | 39.25 | 53.15 | 144.88 | 1743.07 | 1887.96 | 176.54 | 1918.36 | 2094.90 |
| S-13   | 45.79           | 165.61 | 211.40 | 12.01 | 49.93 | 61.94 | 156.19 | 1375.07 | 1531.26 | 128.08 | 1528.63 | 1656.70 |
| S-14   | 62.11           | 247.78 | 309.89 | 16.28 | 52.26 | 68.54 | 229.63 | 1256.20 | 1485.84 | 141.71 | 1563.90 | 1705.61 |
| S-15   | 45.28           | 152.30 | 197.58 | 15.02 | 38.76 | 53.78 | 217.14 | 1333.28 | 1550.42 | 114.30 | 1376.13 | 1490.43 |
| S-16   | 42.88           | 146.56 | 189.44 | 13.10 | 29.08 | 42.18 | 226.42 | 953.64  | 1180.06 | 134.92 | 1005.05 | 1139.97 |
| S-17   | 30.52           | 127.85 | 158.37 | 10.10 | 32.05 | 42.15 | 88.70  | 1142.68 | 1231.38 | 116.84 | 1609.83 | 1726.67 |
| S-18   | 39.21           | 155.95 | 195.16 | 15.40 | 38.36 | 53.77 | 130.39 | 859.77  | 990.16  | 155.75 | 1448.27 | 1604.02 |
| S-19   | 34.58           | 120.73 | 155.32 | 10.17 | 46.08 | 56.25 | 97.34  | 768.05  | 865.39  | 86.28  | 945.91  | 1032.19 |
| S-20   | 37.360          | 121.53 | 158.89 | 7.99  | 38.85 | 46.84 | 119.79 | 771.66  | 891.45  | 96.77  | 785.90  | 882.67  |
| SEM  | 2.426           | 7.455  | 7.413  | 0.794 | 1.879 | 2.043 | 10.024 | 64.794  | 64.745  | 7.885  | 64.218  | 64.762  |
| LSD ( $P<0.05$ )                                 | 4.903           | 15.066 | 14.981 | 1.605 | 3.797 | 4.128 | 20.259 | 130.949 | 144.775 | 15.935 | 129.785 | 130.884 |
| <b>Zn Level (<math>\text{kg ha}^{-1}</math>)</b> |                 |        |        |       |       |       |        |         |         |        |         |         |
| 0  | 31.29           | 147.77 | 145.54 | 9.10  | 29.11 | 38.21 | 122.27 | 879.54  | 1001.81 | 99.94  | 1009.54 | 1109.48 |
| 2  | 38.71           | 172.50 | 169.97 | 11.36 | 35.24 | 46.60 | 148.54 | 1065.75 | 1214.28 | 120.76 | 1194.38 | 1315.14 |
| 4  | 44.96           | 197.34 | 194.65 | 12.76 | 38.61 | 51.37 | 172.52 | 1186.98 | 1359.50 | 136.32 | 1407.96 | 1544.28 |
| 6  | 48.33           | 218.13 | 215.23 | 13.73 | 42.85 | 56.58 | 178.82 | 1334.00 | 1512.81 | 147.25 | 1580.75 | 1728.00 |
| 8  | 51.17           | 226.73 | 223.84 | 14.37 | 45.07 | 59.44 | 189.51 | 1382.14 | 1571.65 | 156.17 | 1646.28 | 1802.45 |
| SEM  | 1.213           | 3.727  | 3.706  | 0.397 | 0.939 | 1.021 | 5.012  | 32.397  | 32.373  | 3.942  | 32.109  | 32.381  |
| LSD ( $P<0.05$ )                                 | 2.451           | 7.533  | 7.490  | 0.802 | 1.899 | 2.064 | 10.130 | 65.475  | 130.850 | 7.968  | 64.892  | 65.442  |
| Interaction                                      |                 |        |        |       |       |       |        |         |         |        |         |         |
| SEM  | 5.425           | 16.669 | 16.575 | 1.775 | 4.202 | 4.568 | 22.415 | 144.885 | 65.425  | 17.631 | 143.596 | 144.812 |
| LSD ( $P<0.05$ )                                 | Non-Significant |        |        |       |       |       |        |         |         |        |         |         |

### Conclusions

The basal addition  $8.0 \text{ kg Zn ha}^{-1}$  or @ of  $38 \text{ kg ha}^{-1}$   $21\% \text{ ZnSO}_4 \cdot 7\text{H}_2\text{O}$  heighted more as compared to other treatments and also produced more yield components as compared to other levels but similar with  $6.0 \text{ kg Zn ha}^{-1}$  or @ of  $28 \text{ kg ha}^{-1}$ . The plants fertilized with  $8.0 \text{ kg Zn ha}^{-1}$  recorded maximum micronutrients uptake and it was at par with of  $6.0 \text{ kg Zn ha}^{-1}$ .

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