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# Effect of zinc solubilizers on growth and yield of maize (*Zea mays* L.)

**J Neelima, Dr. CH Sujani Rao, Dr. M Latha and Dr. PVN Prasad**

**J Neelima**
M.Sc. Student, Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, Andhra Pradesh, India

**Dr. CH Sujani Rao**
Professor, Department of Environmental Sciences, APGC, Lam, Guntur, Andhra Pradesh, India

**Dr. M Latha**
Associate Professor, Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, Andhra Pradesh, India

**Dr. PVN Prasad**
Professor, Department of Agronomy, Agricultural College, Bapatla, Andhra Pradesh, India

**Corresponding Author:**
**J Neelima**
M.Sc. Student, Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, Andhra Pradesh, India

## Abstract
A field experiment entited "Studies on effect of zinc solubilizers on soil properties, growth and yield of maize (*Zea mays* L.)" was conducted at Agricultural College Farm, Bapatla, during *rabi,* 2020. The experiment was laid out in randomized block design (RBD) with seven treatments replicated thrice. The experiment soil was clayey in texture, slightly alkaline in reaction (pH 7.89), electrical conductivity of 0.60 $dSm^{-1}$(non-saline), medium in organic carbon (0.60%), available nitrogen (310 kg $ha^{-1}$), available phosphorus (54.96 kg $P_2O_5$ $ha^{-1}$) and high in available potassium (402 kg $K_2O$ $ha^{-1}$), sufficient in Fe, Mn and Cu and slightly deficient in zinc. The results revealed that, significant improvement in plant height (84 cm) and dry matter accumulation(841 kg $ha^{-1}$), kernel (6088 kg $ha^{-1}$) and stover (7340 kg $ha^{-1}$) yield were recorded in the treatment $T_5$ (RDF+ soil application of zinc Sulfate @ 50 kg/ha + zinc solubilizers) compared to all other treatments.

**Keywords:** Zinc, zinc solubilizers, growth and yield

## Introduction
Maize (*Zea mays* L.), is the most important cereal grown worldwide, which belongs to grass family Poaceae. It is commonly known as `Queen of cereals' because of its high yield potential and its wide range of uses among different agro-industries. It occupies third position in India next to rice and wheat. United States of America is the leading producer of maize contributing to nearly 37% of world's production. In India, it is primarily grown for its grain and occupies an area of 9.70 m ha with a production of 28.7 m t with on average productivity of 3032 kg $ha^{-1}$. Major producers in India are Karnataka followed by Maharashtra (12.33%) and Madhya Pradesh (12.32%). Andhra Pradesh occupies an area of 3.37 lakh ha producing 23.26 lakh tones with an average productivity of 6911 kg $ha^{-1}$.
Zinc is known to be essential for plants and play multiple roles in basic biochemical processes in plants (Alloway, 2009) [1]. Among different micronutrients, zinc is the most often deficient element in corn production and most likely to elicit a yield response when applied as fertilizer. Sufficient zinc supply is very important for maize flowering and corn development. Zinc plays critical role in plant physiological pathways like photosynthesis, protein synthesis, defense against disease, seed production *etc*. 96-99 per cent of applied zinc fertilizers transforms into various unavailable forms like sphelarite, augite, biotite, hornblende *etc*. Foliar spray is most effective method for zinc application but it is too costly to be widely practiced. Likewise, the difficulty in obtaining high quality fertilizers and spreading them evenly on the soil can be unaffordable. Therefore, use of zinc solubilizing microorganisms helps in solubilizing zinc from inorganic and organic pools of total soil zinc.

## Materials and Methods
The experiment was conducted at the Agricultural College Farm, Bapatla located in Krishna agro-climatic zone of Andhra Pradesh. The experiment soil was clayey in texture, slightly alkaline in reaction, electrical conductivity was non-saline, medium in organic carbon, available nitrogen, available phosphorus, high in available potassium and sufficient in Fe, Mn and Cu and slightly deficient in zinc. Recommended dose of nitrogen, phosphorus and potassium (200:60:50 kg $ha^{-1}$) were applied in the form of urea, single super phosphate and muriate of potash, respectively. Phosphorus was applied two days before sowing, $1/3^{rd}$ dose of nitrogen and full dose of potash were applied equally on the day of sowing to all the plots. Zinc solubilizer– *Bacillus coagulans* @ 2 kg/ha applied 3 days before the application of fertilizers.

## Results and Discussion

### Plant height (cm)

The data pertaining to plant height of maize at all the crop growth stages as influenced by rate and methods of zinc application were presented in table 1. The maximum plant height (84.0, 207.6 and 215.0 cm) was recorded in the treatment $T_5$ (RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers) followed by $T_4$ (RDF+ soil application of zinc sulfate @ 50 kg/ha) and the minimum plant height (60.0, 151.4 and 158.4 cm) was recorded with the treatment $T_1$ (Recommended dose of fertilizers) at all the stages of crop growth (kneehigh, tasseling and harvest). This might be due to the continuous supply of zinc throughout the growing period which might have improved plant metabolic activity. Application of zinc sulphate and soubilizers improved the supply of inorganic zinc by soubilization, production of different plant growth promoters and sidephores. Zn is associated with tryptophan, which in turn improved the auxin synthesis, cell division, cell elongation resulting in taller plants (Tisdale *et al*., 1985) [10].

**Dry matter accumulation (kg ha$^{-1}$):** The data pertaining to drymatter accumulation of maize at all the crop growth stages as influenced by rate and methods of zinc application were presented in table 2. At all the stages of crop growth significantly higher drymatter accumulation (841, 3423 and 9795 kg ha$^{-1}$) was recorded in the treatment $T_5$ (RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers). At knee high stage, $T_5$ (RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers) was on par with the treatment $T_3$ (RDF+ soil application of zinc sulfate @ 25 kg/ha + zinc solubilizers) and $T_4$ (RDF+ soil application of zinc sulfate @ 50 kg/ha) whereas in tasseling and harvest stages it was on par with the treatment $T_4$ (RDF+ soil application of zinc sulfate @ 50 kg/ha) and $T_7$ (RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers). Lowest drymatter accumulation (714, 2806 and 8242 kg ha$^{-1}$) was recorded in the treatment that received recommended dose of fertilizers ($T_1$). Slaton *et al.* (2005) [9] recorded an increase in drymatter accumulation with application of zinc. Zinc nutrition is known to increase the plant height, which may perhaps cause a significant increase in drymatter production. This results are in accordance with those of Arshewar *et al*. (2018) [2].

**Table 1:** Effect of zinc solubilizers on plant height (cm) at different growth stages of maize

| Treatment | Knee high | Tasseling | Harvest |
|---|---|---|---|
| $T_1$: Recommended dose of fertilizers | 60.0 | 151.4 | 158.4 |
| $T_2$: RDF+ soil application of zinc sulfate @ 25 kg/ha | 74.3 | 167.3 | 166.3 |
| $T_3$: RDF+ soil application of zinc sulfate @ 25 kg/ha + zinc solubilizers | 76.3 | 175.0 | 171.0 |
| $T_4$: RDF+ soil application of zinc sulfate @ 50 kg/ha | 77.0 | 188.4 | 211.2 |
| $T_5$: RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers | 84.0 | 207.6 | 215.0 |
| $T_6$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS | 62.6 | 179.3 | 195.8 |
| $T_7$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers | 67.3 | 185.3 | 203.0 |
| S.Em± | 3.01 | 7.83 | 7.75 |
| CD (p=0.05) | 9.20 | 24.12 | 23.90 |
| CV (%) | 7.28 | 7.56 | 7.11 |

**Table 2:** Effect of zinc solubilizers on drymatter accumulation (kg ha$^{-1}$) at different growth stages of maize

| Treatment | Knee high | Tasseling | Harvest |
|---|---|---|---|
| $T_1$: Recommended dose of fertilizers | 714 | 2806 | 8242 |
| $T_2$: RDF+ soil application of zinc sulfate @ 25 kg/ha | 813 | 2935 | 8417 |
| $T_3$: RDF+ soil application of zinc sulfate @ 25 kg/ha + zinc solubilizers | 829 | 2985 | 8632 |
| $T_4$: RDF+ soil application of zinc sulfate @ 50 kg/ha | 837 | 3384 | 9711 |
| $T_5$: RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers | 841 | 3423 | 9795 |
| $T_6$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS | 725 | 3265 | 9467 |
| $T_7$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers | 738 | 3333 | 9668 |
| S.Em± | 4.48 | 31.50 | 104.80 |
| CD (p=0.05) | 13.53 | 96.21 | 330.40 |
| CV (%) | 7.19 | 7.75 | 6.97 |

### Test weight (100 kernel weight)

The data pertaining to table 3 was not singinificantly influenced by imposed treatments. The higher values of test weight (28.46 g) were recorded in the treatment that received RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers ($T_5$) and the lowest test weight (24.47 g) was recorded in the treatment $T_1$ (Recommended dose of fertilizers). However, increase in test weight with the application of zinc was observed.

Zinc acts as catalyst in various growth processes, hormone production and protein synthesis (Ramkala *et al.*, 2008) [7] and increases the test weight of kernels due to increased conversion of sugar to starch in plant system (Parthasarthy *et al*., 1984) [5].

**Kernel yield (kg ha$^{-1}$):** Data on kernel yield presented in the table 3 showed that the kernel yield of maize was significantly influenced by the imposed treatments. Significantly higher (6088 kg ha$^{-1}$) kernel yield was recorded in $T_5$ (RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers) and it was on par with the treatments $T_4$ (RDF+ soil application of zinc sulfate @ 50 kg/ha), $T_6$ (RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS) and $T_7$ (RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers). The minimum kernel yield (4748 kg ha$^{-1}$) was registered in $T_1$ (Recommended dose of fertilizers). The treatments that received soil application of zinc @ 50 kg ha$^{-1}$ ($T_5$ and $T_4$) recorded higher values of kernel yield than the treatments that received foliar application of zinc ($T_6$ and $T_7$).

This increment in the kernel yield of maize was due to increase in cob length, number of kernels per cob and 100 kernel weight as reported by Mohsin *et al.* (2014) [4]. Higher yield due to zinc fertilization was also attributed to the enhanced synthesis of carbohydrates and their transport to site of kernel production (Peddababu *et al.*, 2007) [6]. Foliar application of zinc at critical stages enhanced the availability of zinc thus improves the yield. The increase in kernel yield due to zinc application might be attributed the to benefical effects of zinc on chlorophyll and auxin contents which influence photosynthesis. Also foliar application of zinc might have raised drymatter transformation from source to sink and thus significantly reflected in kernel yield (Zayed *et al.* 2011) [12].

**Stover yield (kg ha$^{-1}$)**

The data on stover yield of maize presented in the table 3 showed that the stover yield of maize significantly influenced by rate and methods of zinc application. Significantly highest (7340 kg ha$^{-1}$) stover yield was recorded in $T_5$ (RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers) and it was on par with the treatment $T_4$ (RDF+ soil application of zinc sulfate @ 50 kg/ha), $T_6$ (RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS) and $T_7$ (RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers). While lowest stover yield (6208 kg ha$^{-1}$) was recorded in the treatment that received Recommended dose of fertilizers (RDF). Numerically higher stover yield was recorded in the treatments that received combined application of zinc fertilizers with zinc solubilizers than the application of zinc fertilizers alone.

Zinc fertilization resulted in early growth of seedling and superior nutrition which further enhanced drymatter accumulation in maize thus increasing stover yield (Shakoor *et al*., 2018) [8].

**Harvest index (%)**

The data presented in the table 3, revealed that rate and methods of application of zinc did not show any significant effect on harvest index of maize. The harvest index of maize ranged from 43.3% to 45.3%. Numerically higher value of Harvest index (45.3%) was recorded in the treatment that received RDF+ soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers ($T_5$). However, the lowest harvest index was recorded in recommended dose of fertilizers (43.3%). This increase might be due to efficiency of this treatment in converting drymatter into grain. Similar results were reported by Wei *et al.* (2012) [11] and (Haghi *et al.*, 2016) [3].

Harvest index shows the physiological efficiency of plant to convert the fraction of photo-assimilates to kernel yield.

**Table 3:** Effect of zinc solubilizers on yield of maize

| Treatment | Test weight (g) | Kernel yield (kg ha$^{-1}$) | Stover yield (kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| $T_1$: Recommended dose of fertilizers | 24.47 | 4748 | 6208 | 43.3 |
| $T_2$: RDF+ soil application of zinc sulfate @ 25 kg/ha | 25.70 | 4980 | 6468 | 43.5 |
| $T_3$: RDF+ soil application of zinc sulfate @ 25 kg/ha + zinc solubilizers | 25.86 | 5178 | 6578 | 44.0 |
| $T_4$: RDF+ soil application of zinc sulfate @ 50 kg/ha | 27.96 | 5969 | 7235 | 45.2 |
| $T_5$: RDF + soil application of zinc sulfate @ 50 kg/ha + zinc solubilizers | 28.46 | 6088 | 7340 | 45.3 |
| $T_6$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS | 26.60 | 5569 | 6784 | 45.0 |
| $T_7$: RDF+ foliar spray of zinc sulfate @ 0.2% at 30 and 55 DAS + zinc solubilizers | 27.33 | 5679 | 6908 | 45.1 |
| S.Em± | 0.84 | 276 | 234 | 1.73 |
| CD (p = 0.05) | NS | 851 | 723 | NS |
| CV (%) | 7.48 | 8.76 | 6.99 | 6.52 |

**Conclusion**

These results showed that soil application of zinc with recommended fertilizers increase in the plant growth and yield of maize crop followed by foliar application zinc with recommended fertilizers compared to control. Soil application of zinc recorded significantly higher growth and yield due to attributed to better performance through adequate availability of major and micro nutrients in soil.

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