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# Evaluation of Nano Zinc Effect on Performance of Lentil (*Lens culinaris* Medik.)

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## ABSTRACT

**Background:** Considering the higher efficiency of nano fertilizers than chemical ones, the current study on nano Zn was undertaken to evaluate its effects on growth, yield, uptake and economics over other Zn sources on lentil.

**Methods:** Field experiment was carried out during *rabi* seasons of 2019-20 and 2020-21 at the Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India with seven treatments using different sources of Zn through foliar and soil application in randomised block design replicated thrice. Zn uptake was calculated after testing Zn concentration through wet digestion followed by atomic absorption spectrophotometer determination of collected samples.

**Result:** Pooled result of the experiment revealed that foliar spray of nano Zn @ 20 ppm at 30 and 50 DAS ($T_5$) resulted significantly higher plant height, LAI, dry matter accumulation, 1000 seed weight, number and dry weight of nodules plant$^{-1}$, uptake of Zn, economics. This treatment produced 29.34% and 30.33% more seed and stover respectively than without Zn application.

**Key words:** Economics, Growth, Lentil, Nano Zn, Uptake, Yield, ZnO, $ZnSO_4$.

## INTRODUCTION

Lentil is one of the important and oldest *rabi* pulse in India and a major source of vegetable protein (Singh *et al.,* 1997 and Singh *et al.,* 2011). Current area under lentil is 1.30 m ha with production of 1.10 mtonnes and average productivity of 847 kg ha$^{-1}$ (Indiastat, 2019-20). But lentil cultivation in our country is generally practice after rice in residual soil fertility with minimum efforts, therefore stagnant in production was found in this crop (Ali *et al.,* 2012). Besides that, indiscriminate use of high analysis chemical fertilizer leads to deficiency of micronutrients both in soil and plant and deteriorate the productivity of pulse (Ali *et al.,* 2012). Zn deficiency is the most extensive problem in India as almost 40% of the soil is deficit of this micronutrient (Shukla *et al*., 2014). To correct the deficiency inclusion of micronutrients either through soil application or foliar spray is necessary for maintaining the soil health and productivity.

Requirement of Zn in legumes is important because of its specific role in nodule formation, N-metabolism, plant and root growth, synthesis of chlorophyll and enzymatic processes (Desta *et al*., 2015). Use of nanoparticles as nutrient source has opened a new era as it poses novelty in increasing nutrient use efficiency without polluting the agro-ecology (Jyothi and Hebsur, 2017) due to its nano range (<100 nm) particle size which increases the specific surface area and particles per unit area provides greater surface contact, penetration, availability and uptake of nutrients (Tarafdar *et al.,* 2012). Several attempts have been made to evaluate the efficacy of zinc nanoparticles through foliar spray towards enhancing production in various crops. Keeping in this mind, an experiment was laid out in lentil to study the effect of nano zinc on growth, yield, Zn uptake and economics under different treatments.

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## MATERIALS AND METHODS

The experiment was conducted at instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, during *rabi* season of 2019-20 and 2020-21 on medium land, gangetic alluvial soil. The texture of the soil was sandy loam with a pH of 7.04, organic carbon 0.6%, available nitrogen 189.10 kg ha$^{-1}$, available phosphorus 39.25 kg ha$^{-1}$, available potassium 184.50 kg ha$^{-1}$ and Zn 0.52 mg kg$^{-1}$ (0-15 cm depth). The experiment was laid out in randomized block design (RBD) replicated thrice consisting seven treatments *viz.* $T_1$: Control (no Zn application), $T_2$: $ZnSO_4$ @ 25 kg ha$^{-1}$ soil application as basal, $T_3$: $ZnSO_4$ @ 0.5% foliar spray at 45 DAS, $T_4$: Nano Zn @ 20 ppm foliar spray at 45 DAS, $T_5$: Nano Zn @ 20 ppm foliar spray at 30 and 50 DAS, $T_6$: ZnO @ 20 kg ha$^{-1}$ soil application as basal, $T_7$: ZnO @ 0.2% foliar spray at 45 DAS. The fungal balls of mycelia isolated from *Rhizoctonia bataticola* TFR-6 was used to disperse the salt solution of zinc oxide into nanoparticles, followed by standardization of shape and size of particles through dynamic light scattering (DLS), transmission electron

microscope (TEM) and electron dispersive X-Ray Spectroscopy (EDS) analysis consecutively (Tarafdar *et al.,* 2014). The concentration of Zn nanoparticles formulation was 1000 ppm, from which 20 ppm concentration was prepared by adjusting the volume spray of water. The recommended dose of fertilizers (20:40:20 kg/ha of N: $P_2O_5$: $K_2O$) were applied during basal in all treatments. The variety of lentil was WBL 77(*Moitree)*, which was sown on 20th and 18th November in 2019 and 2020 respectively and harvested on 8th and 5th March in 2020 and 2021 respectively, with 30 cm × 10 cm spacing and seed rate of 30 kg $ha^{-1}$ under irrigated condition with standard agronomic practices and plant protection. During experimental period of 2019-2020, weekly average maximum and minimum temperature ranged from 21.1-29.57°C and 7.51-13.54°C respectively with weekly total rainfall from 0-32 mm. In 2020-2021, weekly average maximum and minimum temperature ranged from 14.37-34.60°C and 7.71-20.41°C respectively with no rainfall. Observations like, plant height, LAI, dry matter accumulation, no. of branches $plant^{-1}$, no. of seeds $pod^{-1}$, no. of pods $plant^{-1}$, 1000 seed weight, seed and stover yield were taken during harvest, root length at 60 DAS, nodules no and dry weight nodules $plant^{-1}$ at 65 DAS were taken. Zn concentration of the seed and stover samples were determined by wet digestion method (Wolf, 1982) followed by atomic absorption spectrophotometer (Model: Perkin Elmer PinAAcle 900F) and uptake of Zn calculated by using following equation:

$$\text{Zn uptake in grain or straw (g ha}^{-1}) = \frac{\text{Yield (kg ha}^{-1}) \times \text{Concentration (mg kg}^{-1})}{10^3}$$

Collected data from field and laboratory were analysed through analysis of variance (Goulden, 1952) and treatment means were compared at critical difference (CD) at 5% level of significance (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### Growth attributes

Pooled result of the experiment showed that different treatments of zinc significantly affected the growth attributes in lentil, among them $T_5$ recorded highest plant height (52.03 cm), LAI (3.48) and dry matter accumulation (447.78 g $m^{-2}$), which is statistically at par with $T_4$ in plant height and dry matter accumulation and control showed the lowest values (Table 1). The improvement in growth attributes could be due to production of growth promoting hormone like auxin, indole acetic acid *etc.* induced by the activity of nano scale Zn, which influences the cell enzyme activation and cell membrane integrity (Havlin *et al.,* 2010). Further, Zn nanoparticle enhanced plant cell metabolic activities than other sources of Zn might be due to faster movement through stomatal and vascular pathways (Tarafdar *et al.,* 2014) because of its large size exclusion limit and its high transport velocity (Eichert *et al.*, 2008). Poornima *et al.* (2019) reported better growth in sorghum due to foliar spray of nano ZnO, García-López *et al.* (2019) reported better growth performance in pepper due to application of nano ZnO.

Different treatments of Zn also influenced the other growth characters like, number of branches $plant^{-1}$, root length, number of nodules $plant^{-1}$ and dry weight of nodules $plant^{-1}$. $T_7$ showed highest number of branches (21.01) in pooled data which was statistically at par with $T_2$, $T_3$ and $T_5$, whereas the lowest number of branches was recorded in control (Table 1). Again, highest no. and dry weight of nodules were found $T_5$ (28.79 and 12.83 mg respectively), which was statistically at par with $T_2$, $T_3$, $T_4$, $T_7$ in case of no. of nodules and with $T_3$, $T_4$, $T_6$, $T_7$ in case of dry weight of nodules $plant^{-1}$and in both cases lowest was found in control (Table 1). However, pooled data showed that $T_4$ treated plants recorded highest root length (24.96 cm) which is statistically at par with $T_5$, $T_6$ and $T_7$ and plants from control showed lowest root length (Table 2). The development of root length induced by nano Zn led to absorption of more nutrients from deeper layer of soil, resulting in greater accumulation of photosynthates and higher growth rate. Better no and dry weight of nodules has found in nano treated plants might be due to role of Zn in synthesis of leghaemoglobin (Marsh and Waters, 1985), which accelerated the total amount of $N_2$ fixation and ultimately dry matter accumulation. Better shoot and root length, root area, dry biomass was reported by Tarafdar *et al.* (2014) in pearlmillet, Raliya and Tarafdar (2013) in cluster bean, Pandey *et al.* (2010) in chickpea and Prasad *et al.* (2012) in peanut.

### Yield attributes and yield

The yield attributes like number of pods $plant^{-1}$, 1000 seed weight and yield of lentil also influenced by different Zn treatment. From the pooled data, it was found that $T_4$ significantly recorded highest number of pods $plant^{-1}$ (125.99) which was statistically at par with $T_2$, $T_3$ and $T_5$ (Table 2). While highest 1000 seed weight (21.25 g) was found in $T_5$, which was statistically at par with $T_4$ and $T_7$. Whereas, lowest was found in control in both (Table 2). On the other hand, number of seeds $pod^{-1}$ was found to be non-significant among the treatments. From pooled result, it was found that lentil grown with the application of foliar spray of nano Zn @ 20 ppm at 30 and 50 DAS ($T_5$) exhibited highest seed (1312.16 kg $ha^{-1}$) and stover yield (3260.39 kg $ha^{-1}$) and lowest was recorded in control (without Zn application) (Table 2). Improvement in number of pods $plant^{-1}$, 1000 seed weight could have resulted due to higher photosynthetic activity enhanced the seed yield. Similarly, stover yield increased due to accelerated process of cell division and cell elongation owing to application of nano Zn. Higher grain/seed yield was reported by Tarafdar *et al.* (2014) in pearlmillet, Poornima *et al.* (2019) in sorghum, Raliya and Tarafdar (2013) in cluster bean, Prasad *et al.* (2012) in peanut, García-López *et al.* (2019) in pepper.

**Table 1:** Growth attributes and nodulation of lentil under different treatments.

| Treatments | Plant heigth (cm) | | | LAI | | | Dry matter accumulation (g $m^{-2}$) | | | No. of branches $plant^{-1}$ | | | No. of nodules $plant^{-1}$ | | | Dr weight of nodules $plant^{-1}$(mg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 -20 | 2020 -21 | Pooled | 2019 -20 | 2020 -21 | Pooled | 2019 -20 | 2020 -21 | Pooled | 2019 -20 | 2020 -21 | Pooled | 2019 -20 | 2020 -21 | Pooled | 2019 -20 | 2020 -21 | Pooled |
| $T_1$- Control (no Zn application) | 41.38 | 42.08 | 41.73 | 2.85 | 2.98 | 2.92 | 359.13 | 367.47 | 363.30 | 15.17 | 15.23 | 15.20 | 22.85 | 24.15 | 23.50 | 8.32 | 8.69 | 8.51 |
| $T_2$- $ZnSO_4$ @ 25 kg/ha soil application as basal | 43.83 | 45.25 | 44.54 | 2.90 | 3.01 | 2.96 | 373.68 | 389.41 | 381.55 | 18.82 | 19.36 | 19.09 | 25.70 | 26.68 | 26.19 | 9.85 | 10.32 | 10.09 |
| $T_3$- $ZnSO_4$ @ 0.5% foliar spray at 45 DAS | 47.67 | 46.95 | 47.31 | 3.17 | 3.14 | 3.16 | 401.33 | 396.36 | 398.85 | 19.28 | 18.45 | 18.87 | 26.13 | 28.87 | 27.50 | 10.65 | 11.87 | 11.26 |
| $T_4$- Nano Zn @ 20 ppm foliar spray at 45 DAS | 50.17 | 51.47 | 50.82 | 3.35 | 3.48 | 3.42 | 424.09 | 430.84 | 427.47 | 19.39 | 18.05 | 18.72 | 26.60 | 26.74 | 26.67 | 12.09 | 11.96 | 12.03 |
| $T_5$- Nano Zn @ 20 ppm foliar spray at 30 and 50 DAS | 51.41 | 52.65 | 52.03 | 3.42 | 3.53 | 3.48 | 443.85 | 451.71 | 447.78 | 20.21 | 21.63 | 20.92 | 28.09 | 29.48 | 28.79 | 12.51 | 13.14 | 12.83 |
| $T_6$- ZnO @ 20 kg/ha soil application as basal | 46.43 | 44.41 | 45.42 | 2.95 | 3.05 | 3.00 | 382.21 | 399.45 | 390.83 | 17.54 | 19.96 | 18.75 | 24.31 | 25.48 | 24.90 | 10.10 | 11.58 | 10.84 |
| $T_7$- ZnO @ 0.2% foliar spray at 45 DAS | 45.43 | 47.87 | 46.65 | 3.26 | 2.96 | 3.11 | 412.27 | 405.36 | 408.82 | 21.12 | 20.89 | 21.01 | 26.10 | 27.86 | 26.98 | 11.57 | 12.08 | 11.83 |
| S.Em (±) | 1.21 | 1.38 | 1.31 | 0.04 | 0.06 | 0.05 | 8.67 | 10.57 | 9.62 | 0.62 | 0.78 | 0.70 | 0.84 | 1.02 | 0.92 | 0.56 | 0.78 | 0.67 |
| CD at 5% | 3.54 | 4.20 | 3.87 | 0.11 | 0.20 | 0.16 | 25.45 | 31.58 | 28.52 | 2.03 | 2.37 | 2.20 | 2.60 | 3.15 | 2.87 | 1.63 | 2.38 | 2.01 |

**Table 2:** Root length, yield attributes and yield of lentil under different treatments

| Treatments | Root length (cm) | | | Number of pods plant$^{-1}$ | | | Number of seeds pod$^{-1}$ | | | 1000-seed weight (g) | | | Seed yield (kg ha$^{-1}$) | | | Stover yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled |
| $T_1$- Control (no Zn application) | 17.81 | 18.22 | 18.02 | 108.67 | 116.87 | 112.77 | 1.51 | 1.46 | 1.49 | 18.67 | 19.52 | 19.10 | 1007.93 | 1021.27 | 1014.60 | 2489.83 | 2513.18 | 2501.50 |
| $T_2$- $ZnSO_4$ @ 25 kg/ha soil application as basal | 18.62 | 19.98 | 19.30 | 114.33 | 125.36 | 119.85 | 1.48 | 1.56 | 1.52 | 19.27 | 20.18 | 19.73 | 1020.66 | 1033.99 | 1027.33 | 2511.65 | 2604.98 | 2558.31 |
| $T_3$- $ZnSO_4$ @ 0.5% foliar spray at 45 DAS | 19.01 | 18.67 | 18.84 | 116.33 | 127.14 | 121.74 | 1.63 | 1.47 | 1.55 | 19.89 | 19.17 | 19.53 | 1137.41 | 1145.61 | 1141.51 | 2793.53 | 2844.03 | 2818.78 |
| $T_4$- Nano Zn @ 20 ppm foliar spray at 45 DAS | 25.74 | 24.17 | 24.96 | 122.67 | 129.32 | 125.99 | 1.60 | 1.49 | 1.55 | 20.77 | 21.59 | 21.18 | 1267.34 | 1292.67 | 1280.01 | 3148.35 | 3061.81 | 3105.08 |
| $T_5$- Nano Zn @ 20 ppm foliar spray at 30 and 50 DAS | 23.39 | 24.69 | 24.04 | 126.33 | 122.54 | 124.44 | 1.55 | 1.60 | 1.58 | 20.53 | 21.96 | 21.25 | 1315.32 | 1308.99 | 1312.16 | 3308.30 | 3212.48 | 3260.39 |
| $T_6$- ZnO @ 20 kg/ha soil application as basal | 19.89 | 20.66 | 20.28 | 112.00 | 118.36 | 115.18 | 1.59 | 1.51 | 1.55 | 19.53 | 19.07 | 19.30 | 1143.94 | 1120.94 | 1132.44 | 2819.85 | 2732.35 | 2776.10 |
| $T_7$- ZnO @ 0.2% foliar spray at 45 DAS | 21.66 | 21.29 | 21.48 | 118.33 | 117.25 | 117.79 | 1.65 | 1.59 | 1.62 | 20.38 | 21.59 | 20.99 | 1228.76 | 1236.09 | 1232.43 | 3081.90 | 3110.23 | 3096.06 |
| S.Em (±) | 1.56 | 1.87 | 1.72 | 1.89 | 2.29 | 2.09 | 0.08 | 0.06 | 0.07 | 0.15 | 0.28 | 0.22 | 9.67 | 9.94 | 9.81 | 51.18 | 49.85 | 50.51 |
| CD at 5% | 4.56 | 5.68 | 5.12 | 5.58 | 6.92 | 6.25 | NS | NS | NS | 0.43 | 0.84 | 0.64 | 30.23 | 30.95 | 30.59 | 146.07 | 147.08 | 146.57 |

**Table 3:** Concentration and uptake of Zn and economics (pooled) of lentil under different treatments.

| Treatments | Concentration of Zn (mg $g^{-1}$) | | | | | | Uptake of Zn (g $ha^{-1}$) | | | | | | Economics (pooled) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed | | | Stover | | | Seed | | | Stover | | | | | | |
| | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | 2019-20 | 2020-21 | Pooled | Cost of cultivation (Rs. $ha^{-1}$) | Gross return (Rs. $ha^{-1}$) | Net return (Rs. $ha^{-1}$) | B:C ratio |
| $T_1$- Control (no Zn application) | 36.99 | 40.84 | 38.92 | 31.19 | 33.76 | 32.48 | 36.88 | 42.07 | 39.48 | 75.36 | 82.44 | 78.90 | 28200 | 50730 | 22530 | 1.79 |
| $T_2$- $ZnSO_4$ @ 25 kg/ha soil application as basal | 41.79 | 44.97 | 43.38 | 34.11 | 37.93 | 36.02 | 43.25 | 47.40 | 45.33 | 86.61 | 99.21 | 92.91 | 30434 | 51366.5 | 20932.5 | 1.68 |
| $T_3$- $ZnSO_4$ @ 0.5% foliar spray at 45 DAS | 43.61 | 46.47 | 45.04 | 34.90 | 38.94 | 36.92 | 48.40 | 54.04 | 51.22 | 96.89 | 111.15 | 104.02 | 29309 | 57075.5 | 27766.5 | 1.95 |
| $T_4$- Nano Zn @ 20 ppm foliar spray at 45 DAS | 43.46 | 46.86 | 45.16 | 35.57 | 38.43 | 37.00 | 56.02 | 59.57 | 57.80 | 109.99 | 118.97 | 114.48 | 30684 | 64000.5 | 33316.5 | 2.08 |
| $T_5$- Nano Zn @ 20 ppm foliar spray at 30 and 50 DAS | 45.38 | 47.64 | 46.51 | 36.83 | 39.04 | 37.94 | 58.69 | 61.36 | 60.02 | 123.64 | 127.52 | 125.58 | 31168 | 65608 | 34440 | 2.10 |
| $T_6$- ZnO @ 20 kg/ha soil application as basal | 42.42 | 46.65 | 44.54 | 33.51 | 37.46 | 35.49 | 47.53 | 54.29 | 50.91 | 92.79 | 103.65 | 98.22 | 31184 | 56622 | 25438 | 1.81 |
| $T_7$- ZnO @ 0.2% foliar spray at 45 DAS | 43.31 | 45.52 | 44.42 | 34.90 | 38.49 | 36.70 | 52.82 | 56.37 | 54.59 | 105.56 | 118.81 | 112.19 | 29784 | 61621.5 | 31837.5 | 2.06 |
| S.Em(±) | 0.57 | 0.73 | 0.65 | 0.60 | 0.84 | 0.72 | 2.14 | 2.46 | 2.30 | 3.51 | 4.22 | 3.86 | - | - | - | - |
| CD at 5% | 1.70 | 2.12 | 1.91 | 1.77 | 2.03 | 1.87 | 6.52 | 7.28 | 6.90 | 10.71 | 12.76 | 11.73 | - | - | - | - |

(Prices: Selling price seed-Rs.50/kg; Input: Urea- Rs.7/kg, SSP- Rs.8/kg, MOP- Rs. 14/kg, $ZnSO_4$ - Rs.50/kg, ZnO- Rs.100/kg, Nano Zn- Rs. 250 per 500 ml, Mandays-Rs.328).

### Zn concentration and uptake

Different treatments significantly affected the Zn concentration in plant. The highest concentration in seed (46.51 mg $g^{-1}$) and stover (37.94 mg $g^{-1}$) were recorded in $T_5$ and lowest from control (Table 3). Accordingly, the highest uptake was noted in seed (60.02 g $ha^{-1}$) and stover (125.58 g $ha^{-1}$) in $T_5$, which is statistically at par with $T_4$ and $T_3$, whereas lowest uptake found in control (Table 3). Uptake of Zn in seed and stover is influenced by the concentration of the nutrient and their respective yield. The concentration of Zn in seed and stover markedly facilitated by the better translocation, assimilation and use efficiency of foliar applied nano Zn particles.

### Economics

Economic analysis of the pooled data indicated that $T_5$ improved the net income (Rs.34440) and benefit: cost ratio (BCR) (2.10) due to higher production with appreciable cost of cultivation resulting in higher net return against other treatments, whereas, lowest net return (Rs.20932.50) and BCR (1.68) found in $T_2$ (Table 3).

## CONCLUSION

The study concluded that foliar spray of nano Zn @ 20 ppm at 30 and 50 DAS can positively improve the growth, yield and economic returns of lentil. This may be a great way to reduce the load of commercial fertilizer on soil and correct micronutrient deficiency by application of nano scale nutrient in lesser quantity.

### Conflict of interest

All authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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