# NUMERICAL DATA

## Phytotoxicity of nano-zinc oxide to tomato plant (*Solanum lycopersicum L*): Zn uptake, stress enzymes response and influence on non-enzymatic antioxidants in fruits (2019)

Effect of n-ZnO on chlorophyll contents (mg/g fw) of Solanum lycopersicum L. (30 day exposure)

| | Chl-a (30 day exposure) | Chl-b (30 day exposure) | T-Chl |
|---|---|---|---|
| **Control** | 597±157a | 533±138a | 1130±221a |
| **300 mg n-ZnO/kg** | 387±82b | 163±41b | 550±223b |
| **600 mg n-ZnO/kg** | 217±65c | 103±15b | 320±56c |
| **1000 mg n-ZnO/kg** | 300±20c | 190±10b | 490±26c |

(90 day exposure)

| | Chl-a (30 day exposure) | Chl-b (30 day exposure) | T-Chl |
|---|---|---|---|
| **Control** | 607±85[a] | 150±51b | 750±87ab |
| **300 mg n-ZnO/kg** | 657±50a | 190±43a | 847±91a |
| **600 mg n-ZnO/kg** | 433±35b | 227±40a | 660±75ab |
| **1000 mg n-ZnO/kg** | 263±69c | 110±10c | 367±72c |

**Note:** Values are means ± SD. Mean with the same letter(s) along the same column are not statistically different at $p<0.05$ by Turkey.

The nano-zinc oxide significantly affected the chlorophyll contents at early stage of the growth. Chl-a, -b and T-Chl at 30 days were all significantly reduced compared to control for all n-ZnO-treatments. The treatments caused reduction of Chl-a, b and T-Chl by at least 54.3%, 99.6% and 105.4%, respectively at 30 day exposure. The 90-day exposure effect of n-ZnO treatment on chlorophyll contents showed that the treatments did alter the contents of Chl-a, and T-Chl at ≤ 600 mg n-ZnO/kg.

**Source:** https://www.sciencedirect.com/science/article/abs/pii/S2352186418304681

## Comparison study of zinc nanoparticles and zinc sulphate on wheat growth: from toxicity and zinc biofortification (2019)

Effects of Zn treatments on Zn concentration in different parts of wheat

| Treatments | Grain (mg $kg^{-1}$) | | Glume (mg $kg^{-1}$) | | Stem (mg $kg^{-1}$) | | Leaf (mg $kg^{-1}$) | | Root (mg $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **(mg $kg^{-1}$)** | ZnO NPs | ZnSO4 | ZnO NPs | ZnSO4 | ZnO NPs | ZnSO4 | ZnO NPs | ZnSO4 | ZnO NPs | **ZnSO4** |
| **Control** | 18.3e | 18.3cd | 10.4d | 10.4d | 8.7d | 10.4e | 6.6d | 8.7e | 15.5e | **15.5d** |
| **10** | 22.6de | 20.6c | 15.2c | 12.7d | 12.3cd | 12.7e | 8.2cd | 12.3d | 18.4d | **16.2d** |
| **20** | 27.1d | 25.9bc | 16.9c | 15.6c | 15.9c | 15.6d | 9.6c | 15.9c | 20.2cd | **18.7cd** |
| **50** | 43.6c | 29.6b | 12.7cd | 18.5c | 17.5c | 18.5c | 13.5b | 17.5c | 23.4c | **20.3c** |
| **100** | 50.4b | 31.1b | 17.0c | 25.3b | 21.1b | 25.3b | 14.0b | 21.1b | 35.2b | **22.6c** |
| **200** | 52.4b | 35.4b | 28.0b | 25.0b | 22.3b | 25.0b | 11.9bc | 22.3b | 39.0b | **28.8b** |
| **1000** | **60.4a** | **44.2a** | **37.7a** | **31.0a** | **39.7a** | **31.0a** | **20.1a** | **39.7a** | **82.7a** | **39.8a** |

**Note:** Totally different lower case letters followed with values in the same column indicate significant differences between treatments ($p < 0.05$).

Zn can be accumulated in all tissues through soil as shown by results from the pot trial. All plant organs showed increased Zn content with the increase in treatment concentrations. The concentration of Zn in grains increased by 3.3 times and 2.4 times for ZnO NPs and ZnSO4 at 1000 mg kg-1. On the contrary, ZnSO4 was more effective at increasing leaf Zn than ZnO NPs, which increased remarkably from 41% to 356% and 24% to 205%, showed an average rate of 147% and 95% for ZnSO4 and ZnO NPs, respectively. Du et al. (2011) reported the similar results that Zn accumulations were significantly enhanced in different tissues treated with ZnO NPs.

**Source:** https://www.sciencedirect.com/science/article/pii/S0045653519306149

Effects of Zn treatments on grain yield, aboveground biomass and harvest index of wheat

| **Treatments** | **Grain Yield (g pot$^{-1}$)** | | **Above ground Biomass (g pot$^{-1}$)** | | **Harvest Index (%)** | |
|---|---|---|---|---|---|---|
| **(mg kg$^{-1}$)** | ZnO NPs | ZnSO4 | ZnO NPs | ZnSO4 | ZnO NPs | **ZnSO4** |
| **Control** | 12.5b | 12.5c | 33.3cd | 33.3d | 37.5ab | **37.5a** |
| **10** | 13.2ab | 14.5b | 37.1c | 42.4b | 35.6ab | **34.2ab** |
| **20** | 18.6a | 19.4a | 54.4a | 57.4a | 34.2ab | **33.8ab** |
| **50** | 19.5a | 18.6a | 48.8ab | 57.1a | 39.9a | **32.6b** |
| **100** | 16.8b | 18.5a | 44.8b | 52.1a | 37.5ab | **35.5ab** |
| **200** | 15.4b | 13.6bc | 47.2ab | 37.0c | 32.6b | **36.8ab** |
| **1000** | **10.4c** | **8.5d** | **29.3d** | **23.9e** | **35.5ab** | **35.6ab** |

In terms of the harvest index means, at 50 mg kg$^{-1}$, the harvest index increased by 6% for ZnO NPs, while all treatments with ZnSO4 reduced harvest index.

**Source:** https://www.sciencedirect.com/science/article/pii/S0045653519306149

## Effects of zinc fertilizer amendments on yield and grain zinc concentration under controlled environment conditions. (2018)

Table 1: Summary of Zn fertilizer treatments in pot experiment.

| Treatment | Zn Application Method | Zn Application Rate (kg Zn $ha^{-1}$) |
|---|---|---|
| **Control** | N/A[a] | 0.000 |
| **$ZnSO_4$** | Soil | 2.500 |
| **7% Zn lignosulphonate** | Foliar | 0.246 |
| **9% Zn chelated with EDTA** | Foliar | 0.246 |
| **9% Zn chelated with EDTA** | Soil | 0.246 |

**Table 2: Effects of various forms of Zn fertilizer on grain and straw yield (g $pot^{-1}$) of three lentil cultivars.**

| | | Yield (g $pot^{-1}$)[a] | |
|---|---|---|---|
| Fertilizer | Cultivar | Grain | Straw |
| Control | CDC Maxim | 1.47 a | 1.97 c |
| | CDC Imvincible | 1.43 a | 1.92 c |
| | CDC Impower | 1.29 a | 3.00 a |
| Soil $ZnSO_4$ | CDC Maxim | 1.45 a | 1.92 c |
| | CDC Imvincible | 1.38 a | 1.79 c |
| | CDC Impower | 1.37 a | 2.93 a |
| 7% Zn foliar lignosulphonate | CDC Maxim | 1.32 a | 2.19 bc |
| | CDC Imvincible | 1.35 a | 1.91 c |
| | CDC Impower | 1.43 a | 2.71 ab |
| 9% Zn foliar EDTA chelated | CDC Maxim | 1.36 a | 1.84 c |
| | CDC Imvincible | 1.31 a | 1.86 c |
| | CDC Impower | 1.35 a | 2.78 a |
| 9% Zn soil EDTA chelated | CDC Maxim | 1.52 a | 1.85 c |
| | CDC Imvincible | 1.35 a | 1.98 c |
| | CDC Impower | 1.33 a | 2.72 ab |
| SEM[b] | | 0.08 | 0.12 |
| Statistical Analysis | | *P* values | |
| Fertilizer effect | | 0.828 | 0.579 |
| Cultivar effect | | 0.309 | $<0.0001$ |
| Fertilizer × cultivar interaction effect | | 0.662 | 0.334 |

[a]Means with the same letter in the same column are not significantly different (P > .05) as determined by multi-treatment comparisons using the Tukey-Kramer method.

[b]SEM=standard error of mean.

**Table 3: Effects of various forms of Zn fertilizer on grain and straw Zn concentration (mg Zn $kg^{-1}$) of three lentil cultivars.**

| Fertilizer | Cultivar | Zn Concentration (mg Zn $kg^{-1}$)[a] Grain | Straw |
|---|---|---|---|
| Control | CDC Maxim | 36.7 a | 29.5 a |
| | CDC Imvincible | 38.2 a | 31.4 a |
| | CDC Impower | 33.3 a | 31.5 a |
| Soil $ZnSO_4$ | CDC Maxim | 36.2 a | 24.4 a |
| | CDC Imvincible | 35.3 a | 29.1 a |
| | CDC Impower | 33.7 a | 32.2 a |
| 7% Zn foliar lignosulphonate | CDC Maxim | 41.0 a | 30.1 a |
| | CDC Imvincible | 38.4 a | 30.3 a |
| | CDC Impower | 34.9 a | 31.5 a |
| 9% Zn foliar EDTA chelated | CDC Maxim | 41.6 a | 33.2 a |
| | CDC Imvincible | 32.8 a | 31.9 a |
| | CDC Impower | 36.9 a | 31.6 a |
| 9% Zn soil EDTA chelated | CDC Maxim | 37.3 a | 32.8 a |
| | CDC Imvincible | 39.1 a | 30.6 a |
| | CDC Impower | 43.5 a | 30.6 a |
| SEM[b] | | 4.53 | 2.21 |
| Statistical Analysis | | *P* values | |
| Fertilizer effect | | 0.708 | 0.353 |
| Cultivar effect | | 0.719 | 0.569 |
| Fertilizer × cultivar interaction effect | | 0.859 | 0.536 |

[a]Means with the same letter in the same column are not significantly different ($P > 0.05$) as determined by multi-treatment comparisons using the Tukey-Kramer method.
[b]SEM = standard error of mean.

**Table 4: Zinc removal (mg Zn $pot^{-1}$) in lentil cultivars amended with different forms of Zn fertilizer.**

| Cultivar | Zn Uptake and Removal ($\mu$g Zn $pot^{-1}$)[a] Straw | Grain | Total |
|---|---|---|---|
| CDC Maxim | 58.7 b | 54.2 a | 112.9 b |
| CDC Imvincible | 58.1 b | 50.1 a | 108.2 b |
| CDC Impower | 89.9 a | 49.6 a | 139.4 a |
| SEM[b] | 2.92 | 3.00 | 4.54 |
| *P* value | <0.0001 | 0.49 | <.0001 |

[a]Means with the same letter in the same column are not significantly different ($P > 0.05$) as determined by multi-treatment comparisons using the Tukey-Kramer method.
[b]SEM = standard error of mean.

**Source:** https://www.tandfonline.com/doi/full/10.1080/01904167.2018.1462386

## Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mungbeans plant (Vigna radiata) (2017)

Table 1: Plant height (cm) on dry weight basis in mungbean varieties at different concentrations of Zn in solution culture.

| Zn treatments | V1 | V2 | V3 | V4 | Mean ± St. dv |
|---|---|---|---|---|---|
| Control | 19.60b | 19.93d | 19.53bc | 13.03e | 18.02b 3.33 |
| 1 µM | 22.94a | 22.60a | 22.70a | 20.73 cd | 22.24a 1.02 |
| 2 µM | 23.18a | 23.00a | 23.20a | 21.03bc | 22.60a 1.05 |
| Mean ± St.d v | 21.91a | 21.84a | 21.81a | 20.27b | |
| | 2.00 | 1.67 | 1.99 | 4.53 | |

V1 = Ramazan, V2 = Swat mungI, V3 = NM92, V4 = KMI.
St. dv = standard deviation.

The mean followed by similar letter (s) are not significantly different at P= 0.05

**Table 2: Chlorophyll contents (mg kg$^{-1}$) on dry weight basis in mungbean varieties at different concentrations of Zn in solution culture.**

| Zn treatments | V1 | V2 | V3 | V4 | Mean ± St. dv |
|---|---|---|---|---|---|
| Control | 35.7f | 73.45de | 93.12 cd | 105.93c | 78.55b 30.63 |
| 1 µM | 36.81f | 145.30b | 210.82a | 221.01a | 153.5a 84.71 |
| 2 µM | 64.54e | 146.07b | 210.57a | 226.08a | 153.5a 84.71 |
| Mean ± St.d v | 45.69c | 123.6b | 171.5a | 184.4a | |
| | 16.34 | 41.71 | 67.88 | 67.95 | |

V1 = Ramazan, V2 = Swat mungI, V3 = NM92, V4 = KMI.
St. d = standard deviation.

The mean followed by similar letter (s) are not significantly different at P = 0.05.

**Table 3: Percent crude protein (dry weight basis) in mungbean varieties at different concentrations of Zn in solution culture.**

| Zn treatments | V1 | V2 | V3 | V4 | Mean ± St. dv |
|---|---|---|---|---|---|
| Control | 12.90f | 11.76f | 13.95ef | 11.54f | 12.54c 1.11 |
| 1 µM | 13.12f | 16.45de | 17.62bcd | 18.12 cd | 16.08b 2.25 |
| 2 µM | 20.54ab | 22.86a | 20.99a | 22.05abc | 21.61a 1.05 |
| Mean ± St.d v | 15.52a | 17.02a | 18.02a | 17.24a | |
| | 4.35 | 5.57 | 3.52 | 4.32 | |

V1 = Ramazan, V2 = Swat mungI, V3 = NM92, V4 = KMI.
St. d = standard deviation.

The mean followed by similar letter (s) are not significantly different at P = 0.05.

**Source :** https://www.sciencedirect.com/science/article/pii/S1878535213002050

## Silicon addition to soybean (Glycine max L.) plants alleviate zinc deficiency (2016)

Table 1. Zinc content (µmol plant−1) at the three sampling times (M1, M2 and M3) after Zn removal from the NS. Values within a column followed by different letters differ significantly ($P < 0.05$, Duncan test).

| Treatmen | Leaves Zn (µmol leaves−1) | | | Stems Zn (µmol stems−1) | | | Root Zn (µmol root−1) | | |
|---|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M1 | M2 | M3 | M1 | M2 | M3 |
| Zn 0 Si (0.0–0.0) | 0.44 d | 0.68 c | 0.84 d | 0.057 c | 0.165 b | 0.270 c | 0.12 d | 0.24 b | 0.37 b |
| Zn 10 Si (0.0–0.0) | 1.29 ab | 1.25 a | 5.26 a | 0.075 bc | 0.052 c | 0.414 a | 0.65 a | 0.22 bc | 2.73 a |
| Zn 0 Si (0.5–0.5) | 1.12 bc | 0.92 b | 1.35 b | 0.083 bc | 0.129 b | 0.358 ab | 0.14 d | 0.15 d | 0.49 b |
| Zn 0 Si (1.0–1.0) | 1.05 c | 1.05 b | 1.19 bc | 0.096 ab | 0.250 a | 0.415 a | 0.27 bc | 0.37 a | 0.38 b |
| Zn 0 Si (0.5–0.0) | 1.36 a | 1.36 a | 1.07 c | 0.075 bc | 0.165 b | 0.278 c | 0.18 cd | 0.16 cd | 0.56 b |
| Zn 0 Si (1.0–0.0) | 1.03 c | 0.96 b | 1.21 bc | 0.118 a | 0.176 b | 0.334 bc | 0.38 b | 0.17 cd | 0.43 b |

**Source:** https://www.sciencedirect.com/science/article/pii/S0981942816302753

## Effect of Zinc fertilization and irrigation regimes on maximum LAI (2016)

| Treatments | $Zn_1$ | $Zn_2$ | $Zn_3$ | $Zn_4$ | $Zn_5$ |
|---|---|---|---|---|---|
| | | Shekhupura (Site 1) | | | |
| $I_1$ | 5.29 | 5.55 | 5.72 | 5.89 | 5.88 |
| $I_2$ | 5.74 | 5.92 | 6.16 | 6.1 | 6.11 |
| $I_3$ | 5.76 | 5.83 | 6.01 | 6.48 | 6.82 |
| $I_4$ | 5.82 | 6.06 | 6.98 | 7.24 | 7.3 |
| $I_5$ | 6.4 | 6.83 | 6.96 | 7.46 | 7.51 |
| | | Sargodha (Site 2) | | | |
| $I_1$ | 3.38 | 3.5 | 3.78 | 3.87 | 3.64 |
| $I_2$ | 3.57 | 3.69 | 3.87 | 3.92 | 3.96 |
| $I_3$ | 3.96 | 4.28 | 4.58 | 4.86 | 5.14 |
| $I_4$ | 3.85 | 4.28 | 4.58 | 5.13 | 5.59 |
| $I_5$ | 4.28 | 4.6 | 5.2 | 5.28 | 5.08 |

**Source:** Shakeel Ahmad at al.(2016),Zinc fertilization under optimum soil moisture improved the aromatic rice productivity,Philippines journal of Crop Science

**Effect of zinc fertilization and irrigation regimes on LAD (2016)**

| Treatments | $Zn_1$ | $Zn_2$ | $Zn_3$ | $Zn_4$ | $Zn_5$ |
|---|---|---|---|---|---|
| **Shekhupura (Site 1)** | | | | | |
| $I_1$ | 296.45 | 307.5 | 316.39 | 325.54 | 330.94 |
| $I_2$ | 301.2 | 320.82 | 326.6 | 336.26 | 347.54 |
| $I_3$ | 313.47 | 330.17 | 339 | 373.88 | 400.55 |
| $I_4$ | 323 | 346 | 376.1 | 407.86 | 424.83 |
| $I_5$ | 345.42 | 378.89 | 394.81 | 422.38 | 411.31 |
| **Sargodha (Site 2)** | | | | | |
| $I_1$ | 192.6 | 209.57 | 223.97 | 234.06 | 232.49 |
| $I_2$ | 210.5 | 219.58 | 236.81 | 244.38 | 251.15 |
| $I_3$ | 233.22 | 260.19 | 276.37 | 293.58 | 309.7 |
| $I_4$ | 235.43 | 259.37 | 278.72 | 313.69 | 337.61 |
| $I_5$ | 255.93 | 278.89 | 307.72 | 320.72 | 312.97 |

**Source:** Naeem Sarwar at al.(2016),Zinc fertilization under optimum soil moisture improved the aromatic rice productivity,Philippines journal of Crop Science

**Effect of zinc fertilization and irregation regimes on NAR (g m-2 day$^{-1}$) (2016)**

| Treatments | $Zn_1$ | $Zn_2$ | $Zn_3$ | $Zn_4$ | $Zn_5$ |
|---|---|---|---|---|---|
| **Shekhupura (Site 1)** | | | | | |
| $I_1$ | 3.34 | 3.4 | 3.49 | 3.6 | 3.77 |
| $I_2$ | 3.79 | 3.74 | 3.67 | 3.58 | 3.4 |
| $I_3$ | 3.86 | 3.64 | 4.06 | 3.67 | 3.66 |
| $I_4$ | 4.6 | 4.53 | 4.37 | 4.15 | 4.18 |
| $I_5$ | 4.11 | 3.78 | 3.75 | 3.62 | 3.68 |
| **Sargodha (Site 2)** | | | | | |
| $I_1$ | 2.92 | 2.98 | 3.07 | 3.18 | 3.35 |
| $I_2$ | 3.37 | 3.22 | 3.25 | 3.16 | 2.98 |
| $I_3$ | 3.44 | 3.22 | 3.64 | 3.25 | 3.24 |
| $I_4$ | 4.18 | 4.11 | 3.95 | 3.73 | 3.76 |
| $I_5$ | 3.14 | 3.36 | 3.33 | 3.2 | 3.26 |

**Source:** Hakoomat ali at al.(2016),Zinc fertilization under optimum soil moisture improved the aromatic rice productivity,Philippines journal of Crop Science