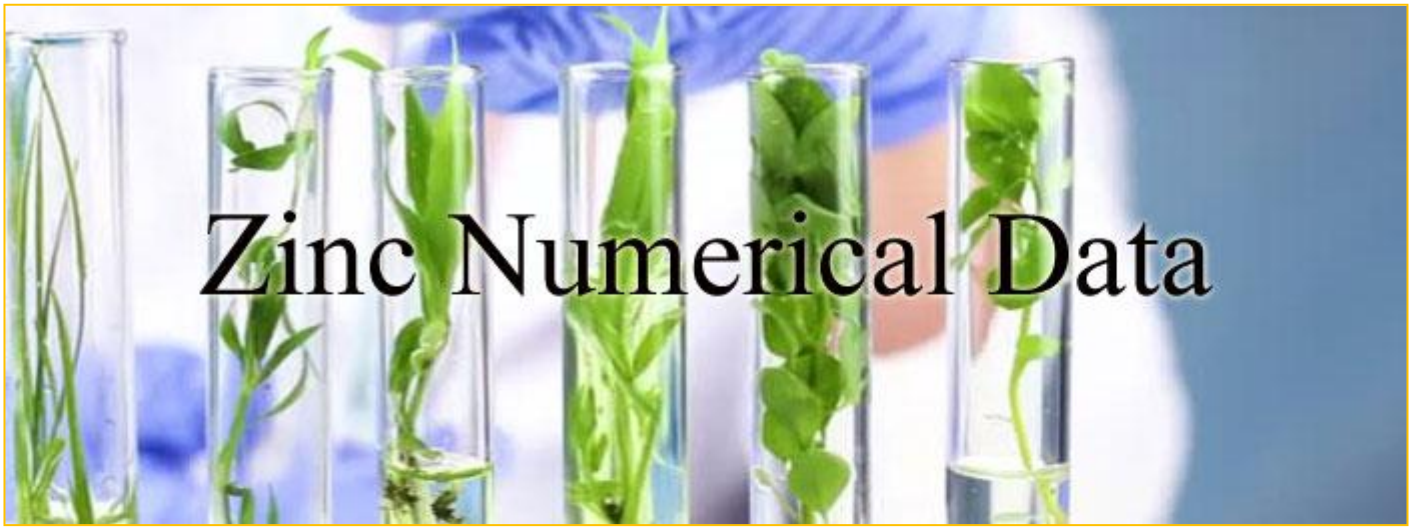

Zinc Plant Uptake as Result of Edaphic Factors Acting (2021)

Table 1: Main characteristics of Albic Retisol (Loamic, Ochric) soil (mean ± standard deviation).

Parameter	Value
Mass fraction of particles (mm) in soil, %	
1–0.25	35.08
0.25–0.05	15.64
0.05–0.01	30.88
0.01–0.005	5.20
0.005–0.001	7.30
<0.002	8.75
<0.001	5.89
Exchangeable cation content, cmol (+) kg^{-1}	
Ca^{2+}	5.20 ± 0.06
Mg^{2+}	0.40 ± 0.09
K^{+}	0.15 ± 0.01
pH_{KCl}	5.05 ± 0.01
pH_{water}	6.04 ± 0.01
C_{org}, %	1.0 ± 0.01
Total acidity (TA), cmol (+) kg^{-1} soil	1.89 ± 0.02
Total exchangeable bases (S), cmol (+) kg^{-1}	5.3 ± 0.2
Labile P_2O_5, mg kg^{-1} (Kirsanov method)	126.9 ± 1.9
Mass fraction of total Zn in native soil, mg kg^{-1}	37.1 ± 2.8

Table 2: The determined values of the parameters used to calculate $PBC(V)_{Zn}$ (according to experiments 1 and 2).

Parameter	Value
Experiment I	
$[Ca + Mg]_{VPs}$, mmol kg^{-1}	526 ± 9
$[Ca + Mg]_{exch}$, mmol kg^{-1}	23.7 ± 4.4
$CR_{(Ca+Mg), exch}$	22.2
$CR_{Zn, exch}$	5.68
Experiment II	
$[Ca + Mg]_{VPs}$, mmol kg^{-1}	613 ± 197
$[Ca^{2+} + Mg^{2+}]_{soil\ solution}$, mM	1.81 ± 0.26
$CF_{(Ca+Mg)}$, dm^3 kg^{-1}	339
CF_{Zn} dm^3 kg^{-1}	640

Table 2: Sequental Extraction Procedure by BCR modified method [21].

#Form (Chemical Fraction of	Procedure

$Zn(^{65}Zn)$/Extraction with	
I.Exchangeable and carbonate bound/Acetic acid, 0.11 M	**I.** A sample of raw soil of known humidity (corresponding to 1 g of absolutely dry soil) without signs of gluing was placed in a 50 mL centrifuge tube. Then, 40 cm^3 of Solution A were added, the tube was closed with a lid, and the material was extracted by shaking for 16 h at 22.5 °C (or overnight) on a rotator. There was no delay between the addition of the extractant solution and the start of shaking. Then, the extract was separated from the solid precipitate by centrifugation at 3000 g for 20 min and the subsequent decantation of the supernatant into a volumetric glass flask (V = 100 mL) with a polished stopper. Next, 20 cm^3 of deionized water were added to the sediment, which was shaken for 15 min on a reciprocating shaker and centrifuged for 20 min at 3000 g, and the washing waters were separated by decantation and combined with the extract in a measuring flask. The solution in the flask was brought to the mark with deionized water, stirred, filtered through a 0.45 microns membrane filter, and analyzed for the content of $Zn(^{65}Zn)$.
II.Associated with reducible Fe–Mn oxides/Hydroxylammonium Chloride (Hydroxylamine Hydrochloride), 0.5 M (pH 1.5, HNO_3, 2 M fixed vol.)	**II.** We added 40 cm^3 of freshly prepared Solution B to the remaining soil after stage (**I**) in a centrifuge tube (see above). The contents were mixed, achieving the complete dispersion of the residue by manual shaking. The centrifuge tube was closed with a lid, and the studied elements were extracted from the soil by mechanical shaking for 16 h at 22.5 °C (night). There was no delay between the addition of the extractant solution and the start of shaking. The procedure for separating the extract, washing the sediment, and preparing the analyte sample was performed in the same way as in step (**I**). It was necessary to carefully ensure that during the last operation we did not accidentally lose part of the solid residue.
III.Associated with oxidizable organic matter and sulfides/Solutions C and D. Solution C: Hydrogen peroxide, 300 mg g^{-1}, i.e., 8.8 M, stabilized HNO_3 to pH 2–3. **Solution D: Ammonium acetate, 1.0 M, adjusted to pH 2.0 with HNO_3.**	**III.** We carefully added 10 cm^3 of Solution C (in small aliquots to avoid losses due to a violent reaction) to the remainder of the soil in a centrifuge tube after stage (**II**). Then, we covered the tube with a lid (loosely) and kept it for 1 h at room temperature (shaking by hand periodically) to oxidize the organic components of the soil with hydrogen peroxide. Then, the oxidation was continued for another 1 h at 85 ± 2 °C in a water bath; during the first ½ hour, centrifuge tubes with soil and extraction solution were periodically manually shaken. The volume of the contents in the test tube with the lid removed was evaporated to approximately V < 3 cm^3. Then, aliquots of Solution C with a volume of 10 cm^3 were repeatedly added to the contents of the centrifuge tube. We covered the tube with a lid (leaky) and again continued the oxidation of its contents for another 1 h at 85 ± 2 °C, periodically manually shaking the centrifuge tubes for the first ½ hour. Then, we removed the lid and evaporated the liquid in the test tube to about V ≈ 1 cm^3, thus preventing the complete drying of the sample. We added 50 mL of Solution D to the cooled wet residue in the test tube and shook it for 16 h at a temperature of 22 ± 5 °C (or overnight). There was delay between the addition of the extractant solution and the start of shaking. The procedure for separating the extract, washing the sediment, and preparing the analysis sample was performed in the same way as in step (**I**).
Solution A. In a fume cupboard, we added 25 ± 0.2 cm^3 of glacial acetic acid to about 0.5 dm^3 of distilled water in a 1 dm^3 graduated polypropylene or polyethylene bottle and made up to 1 dm^3 with distilled water. We took 250 cm^3 of this solution (acetic acid, 0.43 M) and diluted it to 1 dm^3 with distilled water to obtain an acetic acid solution of 0.11 M. **Solution B. We dissolved 34.75 g of hydroxylammonium chloride in 400 cm^3 of distilled water. We transferred the solution to a 1 L volumetric flask, and added 25 cm^3 of 2 M HNO_3 (prepared by weighing from a suitable concentrated solution) by means of a volumetric pipette. We made up to 1 dm^3 with distilled water. We prepared this solution on the same day the extraction was carried out.** **Solution C. 8.8 M water solution H_2O_2 (comprised 300 mg g^{-1} of hydrogen peroxide), was stabilized with HNO_3 to pH 2–3. It is recommended to use hydrogen peroxide acid-stabilized by the manufacturer to pH 2–3.** **Solution D. We dissolved 77.08 g of ammonium acetate in 800 mL of distilled water and adjust the pH to 2.0 ± 0.1 with concentrated HNO_3 and made up to 1 L with distilled water.**	

Source: https://www.mdpi.com/2223-7747/10/11/2496/htm

Impact of Metal-Based Nanoparticles on Cambisol Microbial Functionality, Enzyme Activity, and Plant Growth (2021)

Table 1: Characteristics of biological indicators of Cambisols' condition.

No	Biological Indicators	Measure Unit	Methods
1	total number of bacteria	10^9 bacteria in gram of dry soil weight	luminescent microscopy with the solution of acridine orange, 40×
2	*Azotobacter sp*. abundance	% of the mud balls surrounded by Azotobacter mucus	the method of fouling lumps on the Ashby medium
3	catalase activity	ml O_2 per gram of soil dry weight in 1 min.	by the rate of decomposition of hydrogen peroxide
4	dehydrogenases activity	mg of triphenylformazane per gram of dry soil weight for hour	according to the rate of conversion of triphenyltetrazolium chloride (TPC) to triphenylformazane (TPF)
5	the germination rate of radish seeds	% of germination seeds of contro	germination of radish (*Raphanus sativus L.*) after 7 days of the experiment
6	the length of the radish roots	millimeters	of length of the roots in radish (*Raphanus sativus L.*) after 7 days of the experiment

Source: https://www.mdpi.com/2223-7747/10/10/2080

Table 1: Role of mycorrhizal fungi in mitigating soil nutrient deficiencies.

AMF species	Host plant	Nutrient	Mechanism	Reference
Rhizophagus irregularis	*Medicago truncatula*	P and Zn	MtZIP5 and MtPT4 gene induction increased	(Nguyen et al., 2019)
Mixed AMF	*Leymus chinensis Puccinellia tenuiflora*	P	Increase phytoavailable P in soil, promote P uptake and reduce N:P ratio	(Mei et al., 2019)
Rhizophagus irregularis	Maize	P	Increase root absorption area and soil P availability	(Ven et al., 2019)
Mixed AMF	Temperate tree species	P and N	Increase root exudation and promote P uptake	(Liese et al., 2018)
Rhizophagus irregularis	Barley	Zn	Modify ZIP transporter response and increase grain Zn bioavailability	(Watts-Williams and Cavagnaro, 2018)
Funneliformis mosseae	Cucumber	N, P, K, Ca, S, Zn, Fe, Mg, Mn	Promote nutrient uptake	(Chen et al., 2017)
Glomus mixed species	Sunflower	Fe	Increase iron reductase activity which ensure Fe uptake	(Kabir et al., 2020)
Indigenous mycorrhiza	Maize	K and Mg	Promote nutrient uptake along increase fertilizer efficiency	(Zare-Maivan et al., 2017)
Rhizophagus irregularis	*Medicago truncatula*	Zn	Stimulate the MtZIP6 gene expression and increase root absorption area	(Watts-Williams et al., 2017)
Mixed AMF	Wheat, Barely, Sorghum, maize	P	Increase P uptake and promote plant growth	(Frew, 2019)

Table 2: Mycorrhizal fungi response to metal contamination.

AMF species	Host Plant	Heavy metal	Mechanism	Reference
Funneliformis mosseae	Pepper	Cu	Promote photosynthesis rate and dry mass production	(Ruscitti et al., 2017)
Indigenous mycorrhiza	Wheat	Zn	Promote plant growth thus regulate nutrient uptake	(Zhang et al., 2016)
Glomus versiforme, Rhizophagus intraradices	*Lotus japonica*	Cd	Increase P nutrition and antioxidants activity	(Jiang et al., 2016)
Rhizophagus intraradices	*Brachiaria mutica*	Cr	Accumulate Cr in roots and reduced its translocation towards shoots	(Kullu et al., 2020)
Rhizophagus intraradices	Medicago truncatula	Pb	Immobilize Pb in the cell wall by increasing polysaccharides content in cell	(Zhang et al., 2021)
Rhizophagus irregularis	Willows	Pb and Cu	Immobilize metals in soil	(Dagher et al., 2020)
Mixed species	Carrot and lettuce	Sb	Phytoremediation of Sb	(Pierart et al., 2018)
Rhizophagus intraradices	Pea	As	Regulate Arsenate transporter in root epidermis cells and reduced its uptake	(Alam et al., 2020)
Mixed species	Mung bean	As	Mitigate As toxicity effect on plant growth	(Alam et al., 2019)
Rhizophagus irregularis	*Medicago truncatula*	Zn	Stimulate the MtPT4 gene expression and upregulate P uptake and create dilution effect	(Watts-Williams et al., 2017)
Claroideoglomus and Rhizophagus spp.	Bread wheat	Cd	Reduced its accumulation in wheat grains	(Baghaie et al., 2019)

Source: https://www.sciencedirect.com/science/article/pii/S1319562X21005696

Table 1: Adsorption capacity of zinc from water by a number of selected plant species.

Plant	Adsorption capacity (mg/g)	Reference
Myriophyllum spicatum	13.5	Wang et al. (1996)
Potamogeton lucens	32.4	Schneider and Rubio (1999)
Salvinia herzegoi	18.1	Schneider and Rubio (1999)
Eichhornia crassipes	19.2	Schneider and Rubio (1999)
Ceratophyllum demersum	14	Keskinkan et al. (2004)
Fagus longipetiolata	2	Božić et al. (2013)
Padina sp.	52.65	Sheng et al. (2004)
Sargassum sp	32.5	Sheng et al. (2004)
Ulva sp	35.1	Sheng et al. (2004)
Gracillaria sp.	26	Sheng et al. (2004)
Scagassum	24.2	Vijayaraghavan et al. (2009)
Apium nodiflorum	10.92	Vlyssides et al. (2005)
Chlorella minutissima	33.71	Yang et al. (2015)
Oedogonium sp.	14.65	Bakatula et al. (2014)
Spirogyra insignis	21.1	Romera et al. (2007)
Codium vermilara	23.8	Romera et al. (2007)
Fucus spiralis	53.2	Romera et al. (2007)
Ascophyllum nodosum	42	Romera et al. (2007)
Asparagopsis armata	21.6	Romera et al. (2007)
Chondrus crispus	45.7	Romera et al. (2007)
Spirogyra sp.	0.263	Rajfur et al. (2010)
Laminaria japonica	72.57	Liu et al. (2009)
Eichhornia crassipes	17.5	Rodríguez-Espinosa et al. (201
Myriophyllum spicatum	14	Keskinkan et al. (2007)
Myriophyllum spicatum	6.8	Ng et al. (2003)
Ceratophyllum demersum	13.98	Keskinkan et al. (2007)

Table 2: Accumulation and Zn tolerance in a number of selected plant species.

Plant species	Stock volume (mg/kg	Reference
Conium maculatum	820 ± 90	Mohsenzadeh and Mohammadzadeh (2018)
Stachys inflata	384 ± 40	Mohsenzadeh and Mohammadzadeh (2018)
Reseda lutea	760 ± 45	Mohsenzadeh and Mohammadzadeh (2018)
Eleocharis acicularis	11200	Sakakibara et al. (2011)
Zea mays	31.75 ± 9.38	Li et al. (2017a)
Arthraxon hispidus	56.00 ± 8.80	Li et al. (2017a)
Bidens pilosa	81.09 ± 21.71	Li et al. (2017a)
Salsola collina	30.75 ± 3.65	Li et al. (2017a)
Populus adenopoda	98.39 ± 60.59	Li et al. (2017a)
Broussonetia papyrifera	36.46 ± 13.29	Li et al. (2017a)
Suaeda altissima	489	Lorestani et al. (2011)
Chenopodium album	1458	Lorestani et al. (2011)
Camphorosma monospe	297	Lorestani et al. (2011)
Salsola soda	1256.3	Lorestani et al. (2011)
Thlaspi tatrense	20100	Marques et al. (2009)
Cardaminopsis halleri	13620	Marques et al. (2009)
Dichapetalum gelonioid	30000	Marques et al. (2009)
Viola calaminaria	10000	Marques et al. (2009)
Alhaji cameloron	62.00 ± 8.4	Chehregani et al.(2009)
Amaranthus retroflexus	233.00 ± 36	Chehregani et al.(2009)
Cardaria draba	1850.00 ± 197	Chehregani et al.(2009)
Cydonia oblonga	1564.00 ± 220	Chehregani et al.(2009)
Stipa lessingiana	39.50 ± 6.5	Chehregani et al.(2009)
Scariola orientalis	1468.00 ± 160	Chehregani et al.(2009)
Polygonum aviculare	1262.00 ± 145	Chehregani et al.(2009)

Source: https://www.sciencedirect.com/science/article/pii/S2352554121001777

Improving zinc phytoremediation characteristics in Salix pedicellata with a new acclimation approach (2020)

Table 1: New acclimation approach for *S. pedicellata* clones to tolerate DI100 (20 mg L^{-1} $ZnSO_4$).

Acclimation phases	Time (Days)	$ZnSO_4$ treatment (mg L^{-1} of HS: Hoagland's solution)		
		Induced plants		Control plants
		Low concentrations (mg L^{-1})	Cumulated concentrations (mg L^{-1})	
Tolerance induction phase	0	1.0	1.0	HS
	3	1.1	2.1	HS
	6	1.2	3.3	HS
	9	1.4	4.7	HS
	12	1.6	6.3	HS
	15	1.8	8.1	HS
	18	2.0	10.1	HS
	21	2.1	12.2	HS
	24	2.2	14.4	HS
	27	2.4	16.8	HS
	30	2.6	19.4	HS
	33		20.0	HS
Tolerance maintenance phase	39		20.0	HS
	45		20.0	HS
	51		20.0	HS
	57		20.0	HS

Table 2: Two-way ANOVA test to compare the outcome of $ZnSO_4$ treatments and biomass accumulation between SP-K12 and SP-K20 *S. pedicellata* clones.

Source	Sum of squares	Degree of freedom	Mean squares	*F*-value	Probability	Significance
Aerial part						
A:Clone	2.98	1	2.98	8.84	0.0075	**
B:$ZnSO_4$ treatments	4.13	1	4.13	12.25	0.0023	**
AB	38.10	1	38.10	112.97	0.0000	***
Error	6.75	20	0.34			
Total (Corr.)	51.96	23				
Root part						
A:Clone	3375E − 7	1	3375E − 7	0.01	0.9129	

B:$ZnSO_4$ treatments	0.43	1	0.43	15.79	0.0007	***
AB	1.51	1	1.51	54.68	0.0000	***
Error	0.55	20	0.028			
Total (Corr.)	2.49	23				

The differences were considered significant at $p = 0.01–0.05$ (*); highly significant at $p = 0.001–0.01$ (**); and very highly significant at $p \leq 0.001$ (***).

Table 3: Two-way ANOVA test to compare the effect of DI100 treatments (20 mg L^{-1} $ZnSO_4$) on biomass and Zn bioaccumulation in the SP-K20 clone after 6 days of the treatment (66th day).

Source	Sum of squares	Degree of freedom	Mean squares	*F*-value	Probability	Signification
Biomass						
A:DI_{100} treatments	78.23	1	78.2287	136.13	0.0000	***
B:Time	29.64	1	29.637	51.57	0.0000	***
AB	17.12	1	17.1197	29.79	0.0000	***
Error	11.49	20	0.574677			
Total (Corr.)	136.48	23				
Zn bioaccumulation						
A: DI_{100} treatments	8.27E7	1	8.27E7	477.35	0.0000	***
B:Time	1.54E7	1	1.54E7	88.71	0.0000	***
AB	8.84E6	1	8.84E6	51.02	0.0000	***
Error	3.46E6	20	1.73E5			
Total (Corr.)	1.10E8	23				

The differences were considered significant at $p = 0.01–0.05$ (*); highly significant at $p = 0.001–0.01$ (**); and very highly significant at $p \leq 0.001$ (***).

Source: https://www.tandfonline.com/doi/full/10.1080/15226514.2019.1708862

Potential of water lettuce (*Pistia stratiotes L.*) for phytoremediation: physiological responses and kinetics of zinc uptake (2020)

Table 1: Zn contents in the roots and shoots in water lettuce (*Pistia stratiotes L.*) subjected to different treatments and culture times.

Initial Conc. (mg L^{-1})	**Metal content in the biomass (mg kg^{-1})**				
		24 h	**48 h**	**72 h**	**168 h**
0.7	Root	0.69 ± 0.117	0.73 ± 0.041	0.75 ± 0.136	1.20 ± 0.159
	Shoot	0.17 ± 0.021	0.17 ± 0.011	0.16 ± 0.016	0.40 ± 0.032
1.8	Root	5.96 ± 6.246	6.79 ± 6.795	8.57 ± 8.891	7.66 ± 7.659
	Shoot	0.44 ± 0.022	0.50 ± 0.024	0.65 ± 0.032	1.01 ± 0.015
18.0	Root	23.26 ± 0.708	28.19 ± 1.025	32.75 ± 2.536	46.00 ± 0.979
	Shoot	1.41 ± 0.169	2.40 ± 0.281	2.56 ± 0.092	7.29 ± 0.218
180.0	Root	88.03 ± 0.838	118.21 ± 0.693	105.12 ± 0.397	167.82 ± 0.365
	Shoot	1.41 ± 0.083	5.80 ± 0.021	8.16 ± 0.021	21.58 ± 0.021

Table 2: Percentage Zn removal expressed according to the dry biomass (g) of water lettuce plants subjected to increasing doses of contamination at different culture times.

Initial Conc. (mg.L^{-1})	**% Zn removal from the solution**				
		24 h	**48 h**	**72 h**	**168 h**
0.7	Root	14.2 ± 1.072	12.0 ± 0.505	16.2 ± 0.315	23.9 ± 0.885
	Shoot	9.6 ± 0.068	9.3 ± 0.265	9.7 ± 0.235	20.4 ± 1.098
	Total	23.8 ± 1.140	21.3 ± 0.504	25.9 ± 0.160	44.3 ± 2.211
1.8	Root	33.1 ± 0.904	40.1 ± 0.981	48.0 ± 2.307	53.7 ± 0.119
	Shoot	4.8 ± 0.022	6.8 ± 0.066	9.2 ± 0.107	18.0 ± 0.702
	Total	37.8 ± 1.853	46.9 ± 0.956	57.2 ± 3.873	71.7 ± 0.767
18.0	Root	14.6 ± 0.378	15.6 ± 0.027	14.9 ± 0.727	28.2 ± 0.474
	Shoot	1.6 ± 0.025	3.5 ± 0.224	4.6 ± 0.087	9.6 ± 0.297
	Total	16.2 ± 0.353	19.1 ± 0.248	19.5 ± 1.234	37.8 ± 0.301
180.0	Root	4.2 ± 0.066	5.4 ± 0.066	3.6 ± 0.113	6.8 ± 0.053
	Shoot	0.6 ± 0.030	0.7 ± 0.045	1.4 ± 0.054	2.4 ± 0.095
	Total	4.8 ± 0.095	6.1 ± 0.164	5.0 ± 0.079	9.2 ± 0.096

Average of three repetitions ± standard deviation.

Table 3. Chlorophyll a (Chl a). chlorophyll b (Chlb). total chlorophyll (C total). and carotenoid (Cx + c) contents. the Cha/Chb ratio. Ctotal/Cx + c ratio and the FCI in water lettuce leaves (Pistia stratiotes L.) subjected to increasing doses of Zn at different culture times.

Dependent Variable	**Independent Variable**	**Regression models**	**Regression coefficient**			
As_{Root}	As_{Soil}, pH, EC, OM, CEC,	Y_1 = -1.412+ 0.025 × As **+ 0.493 × pH* + 0.018 × EC + 0.135	**0.96**	**0.945**	**64.975**	**0.0001**
	Al%, Fe%	× OM** – 0.095× CEC – 1.331×Al% *+ 1.63 ×Fe%*				
As_{Straw}	As_{Soil}, pH, EC, OM, CEC,	Y_2 = 0.738 + 0.004 × As_{Soil}** – 0.134 × pH + 0.005 × EC + 0.06 ×	**0.953**	**0.936**	**55.59**	**0.0001**
	Al%, Fe%	OM + 0.013×CEC – 0.38×Al% *+ 0.352 × Fe%*				
As_{Grain}	As_{Soil}, pH, EC, OM, CEC	Y_3 = 0.554 + 0.003 × As ** – 0.127 × pH + 0.004 × EC + 0.055 ×	**0.94**	**0.918**	**42.415**	**0.0001**
	Al%, Fe%	OM + 0.004×CEC – 0.246 × Al%* + 0.195× Fe%*				

Average of three repetitions ± standard deviation.
*Chl a/Chl b = ratio between chlorophyll a and chlorophyll b contents.
*Ctotal/Cx + c = ratio between total chlorophyll (chlorophyll a + b) and carotenoid contents.
*FCI: Falker chlorophyll index.

Table 4: Kinetic parameters of Zn uptake by water lettuce (*Pistia stratiotes L.*) cultivated in nutrient solutions with different concentrations of the element.

Solution Conc. (mg L^{-1})	**Kinetic parameters**	
	K_m (μmol L^{-1})	**V_{max} (μmol g^{-1} h^{-1})**
1.8	1.590 ± 0.035	0.080 ± 0.018
18.0	61.240 ± 2.065	0.189 ± 0.008

Average of three repetitions ± standard deviation.

Table 5. Variation in biomass and root/shoot ratio of water lettuce (*Pistia stratiotes L.*) after 93 h of culture in nutrient solution contaminated with different doses of Zn.

Solution concentration	**Biomass (grams)**		
(mg L^{-1})	**Initial**	**Final**	**Root/shoot ratio**
1.8	42.03 ± 0.494	34.86 ± 0.985	0.43 ± 0.049
18	45.98 ± 0.630	41.91 ± 0.890	0.63 ± 0.042

Average of three repetitions ± standard deviation.

Source: https://www.tandfonline.com/doi/full/10.1080/15226514.2020.1725868

Table 1: Mean leaf areas (square inch) of Cichorium after growing in natural and Zn-contaminated soils for 90 days

Days	Natural soil	Zn-contaminated soil	
	Non-contaminated	1200 mg kg^{-1}	2400 mg kg^{-1}
15	$2.56^{a} \pm 0.05$	$2.64^{a} \pm 0.02$	$2.61^{a} \pm 0.02$
30	$4.10^{b} \pm 0.09$	$3.99^{b} \pm 0.01$	$2.67^{b} \pm 0.04$
45	$8.35^{c} \pm 0.01$	$4.21^{c} \pm 0.05$	$2.31^{c} \pm 0.02$
60	$9.56^{d} \pm 0.10$	$3.54^{de} \pm 0.04$	$2.28^{cd} \pm 0.03$
75	$14.63^{ef} \pm 0.12$	$3.53^{ed} \pm 0.02$	$1.20^{e} \pm 0.01$
90	$14.75^{f} \pm 0.04$	$3.32^{f} \pm 0.05$	$0.95^{f} \pm 0.01$

Means with different letters in the vertical columns are significantly different by t-test at a 95% confidence level

Table 2: Mean leaf biomasses (g) of Cichorium after growing in natural and Zn-contaminated soils for 90 days

Days	Natural soil	Zn-contaminated soil	
	Non-contaminated	1200 mg kg^{-1}	2400 mg kg^{-1}
15	$0.23^{a} \pm 0.01$	$0.24^{a} \pm 0.04$	$0.23^{a} \pm 0.01$
30	$0.41^{b} \pm 0.03$	$0.40^{b} \pm 0.02$	$0.41^{b} \pm 0.02$
45	$0.83^{c} \pm 0.01$	$0.42^{bc} \pm 0.04$	$0.37^{c} \pm 0.02$
60	$1.62^{d} \pm 0.04$	$0.66^{d} \pm 0.03$	$0.36^{cd} \pm 0.04$
75	$1.78^{e} \pm 0.01$	$0.58^{e} \pm 0.03$	$0.25^{ae} \pm 0.01$
90	$1.96^{f} \pm 0.05$	$0.49^{f} \pm 0.03$	$0.19^{f} \pm 0.02$

Means with different letters in the vertical columns are significantly different by t-test at a 95% confidence level

Table 3: Mean leaf length (LL in inch) and mean root length (RL in square inch) of Cichorium after growing in natural and Zn-contaminated soils for 90 days

Days	Natural soil		Zn-contaminated soil			
	Non-contaminated		1200 mg kg^{-1}		2400 mg kg^{-1}	
	LL	RL	LL	RL	LL	RL
15	$4.53^{a} \pm 0.04$	$3.94^{a} \pm 0.05$	$4.30^{a} \pm 0.08$	$2.44^{a} \pm 0.05$	$4.09^{a} \pm 0.12$	$1.97^{a} \pm 0.05$
30	$5.30^{b} \pm 0.02$	$5.67^{b} \pm 0.10$	$4.47^{b} \pm 0.05$	$3.35^{b} \pm 0.04$	$3.65^{b} \pm 0.04$	$1.98^{ab} \pm 0.02$
45	$5.32^{bc} \pm 0.03$	$13.86^{c} \pm 1.02$	$5.07^{c} \pm 0.02$	$5.59^{c} \pm 0.07$	$3.15^{c} \pm 0.20$	$2.05^{c} \pm 0.05$
60	$6.46^{d} \pm 0.07$	$17.17^{d} \pm 0.08$	$4.53^{d} \pm 0.02$	$6.30^{d} \pm 0.12$	$3.11^{cd} \pm 0.05$	$1.99^{ad} \pm 0.02$
75	$6.90^{e} \pm 0.03$	$19.40^{e} \pm 0.03$	$4.16^{e} \pm 0.02$	$3.58^{e} \pm 0.08$	$3.05^{de} \pm 0.01$	$1.88^{e} \pm 0.01$
90	$7.05^{f} \pm 0.00$	$20.47^{f} \pm 0.05$	$4.15^{ef} \pm 0.04$	$2.76^{f} \pm 0.01$	$2.85^{f} \pm 0.03$	$1.87^{ef} \pm 0.02$

Means with different letters in the vertical columns are significantly different by t-test at a 95% confidence level

Table 4: Concentrations of Zn (mg kg^{-1}) in Cichorium leaves after growing in natural and Zn-contaminated soils for 90 days

Days	**Natural Soil**	**Zn-contaminated soil**	
	Non-contaminated	**1200 mg kg^{-1}**	**2400 mg kg^{-1}**
15	$2.31^{a} \pm 0.75$	$334.0^{a} \pm 25.6$	$584.5^{a} \pm 43.4$
30	$5.35^{b} \pm 1.05$	$401.9^{ab} \pm 1.05$	$620.6^{a} \pm 57.4$
45	$9.43^{c} \pm 2.44$	$481.6^{bc} \pm 35.0$	$1136^{b} \pm 68.2$
60	$15.6^{d} \pm 1.50$	$529.5^{c} \pm 30.1$	$1995^{c} \pm 37.6$
75	$25.0^{e} \pm 0.54$	$700.3^{d} \pm 55.6$	$2028^{c} \pm 32.9$
90	$37.5^{f} \pm 3.89$	$809.7^{d} \pm 4.75$	$2232^{d} \pm 16.7$

Means with different letters in the vertical columns are significantly different by t-test at a 95% confidence level

Source: https://link.springer.com/article/10.1007/s00128-020-02960-4

Zinc tolerant plant growth promoting bacteria alleviates phytotoxic effects of zinc on maize through zinc immobilization (2020)

Table 1: Soil sample sites and chemical properties of experimented soil.

Place	**Satellite location**	**EC[a] (dS/m)**	**pH[a]**	**OC (g/kg)**	**Av. N (kg/ha)**	**Av. P (kg/ha)**	**Av. K (kg/ha)**	**DTPA-Zn (mg/kg)**
Mochia, Zawar	24° 21′ 37.6" N 73° 41′ 45.3" E	0.57	7.19	0.55	94.82	20.20	199.36	35.99
Balaria, Zawar	24° 35′ 38.8" N 73° 75′ 21.1" E	0.62	7.25	0.60	81.09	18.22	169.44	39.99

[a]1:2 soil to water ratio, OC, organic carbon; Av. N, available nitrogen (Kjeldahl digestion); Av. P, available phosphorus (Olsen's P_2O_5); Av. K, available potassium (ammonium acetate extractable K_2O).

Table 2: Biochemical characterization of zinc tolerant bacteria.

Strain name	**Starch hydrolysis**	**Citrate utilization**	**Nitrate reduction**	**Gelatin liquefaction**	**Catalase activity**	**Oxidase**
ZTB 15	−	+	−	+	+	−
ZTB 24	+	+	+	−	+	−
ZTB 28	+	+	−	−	+	+
ZTB 29	+	+	−	−	+	−

+, Positive; −, negative.

Table 3: Effect of Zn concentration on biosorption of Zn by ZTB.

Strain name	**Concentration of Zn (mg/L) in the supernatant after biosorptionby ZTB after 72 h**		**% Biosorption of Zn by ZTB after 72 h**	
	Media with 20 mg/L Zn	**Media with 40 mg/L Zn**	**Media with 20 mg/L Zn**	**Media with 40 mg/L Zn**
ZTB 15	1.508 ± 0.196^{a}	2.598 ± 0.252^{a}	92.46	93.51
ZTB 24	3.285 ± 0.020^{c}	9.586 ± 0.121^{c}	83.58	76.04
ZTB 28	1.831 ± 0.050^{b}	3.851 ± 0.059^{b}	90.85	91.87
ZTB 29	1.825 ± 0.309^{ab}	3.597 ± 0.252^{b}	90.88	91.01

Data is presented as means of 3 replicates ± SD (standard deviation). The Mean value followed by same letter in column of each treatment is not significant difference at $p = 0.05$ by Tukey–Kramer HSD test.

Table 4: Plant growth promoting activities of ZTB.

PGPR activity	**ZTB strains**			
	ZTB15	ZTB24	ZTB28	ZTB29
IAA production (μg/mL)	4.83 ± 0.02	4.32 ± 0.040	8.03 ± 0.02	12.54 ± 0.07
ACC deaminase activity	+ +	+	+ +	+
Ammonia production (μg/mL)	1.42 ± 0.23	1.49 ± 0.56	1.48 ± 0.18	1.45 ± 0.86
HCN production	–	–	–	–
GA_3 (μg/mL)	28.20 ± 1.31	60.60 ± 1.50	40.86 ± 1.23	28.10 ± 1.01
Phosphate solublization index	4.60 ± 0.10	3.45 ± 0.10	4.10 ± 0.20	3.85 ± 0.04
Potassium solublization index	4.20 ± 0.05	6.30 ± 0.05	6.33 ± 0.03	8.00 ± 0.10
Silica solublization index	2.23 ± 0.02	2.90 ± 0.01	3.52 ± 0.01	2.30 ± 0.01
Phytase production index	12.12 ± 0.01	11.42 ± 0.01	7.50 ± 0.02	11.42 ± 0.01
Siderophore index (Z/C)	2.08 ± 0.01	1.66 ± 0.01	1.11 ± 0.01	2.00 ± 0.60

+, Positive; ++, medium positive; +++, high positive; −, negative; Data is presented as means of 3 replicates ± SD (standard deviation).

Table 5: In vitro studies on the effect of zinc tolerant bacteria on growth and biomass of maize seedling under Zn stress conditions (1,000 mg Zn/kg planting mixture).

Treatment details	Average shoot length (cm)	Average root length (cm)	Average root number	Average leaf number	Total chlorophyll (µg/mL)
T1: control without Zn and ZTB inoculation	11.50 ± 0.93^{c}	38.50 ± 4.03^{b}	10.52 ± 0.98^{cd}	6.00 ± 1.0^{a}	34.14 ± 4.14^{b}
T2: control with Zn and without ZTB inoculation	8.90 ± 1.03^{bc}	36.50 ± 3.20^{b}	10.13 ± 0.86^{d}	5.00 ± 0.58^{a}	32.83 ± 4.91^{b}
T3: with Zn and ZTB15 inoculation	13.2 ± 1.47^{b}	47.23 ± 2.07^{a}	13.33 ± 1.32^{bc}	5.30 ± 1.15^{a}	47.10 ± 4.0^{a}
T4: with Zn and ZTB24 inoculation	13.26 ± 1.25^{b}	48.56 ± 2.22^{a}	14.33 ± 1.25^{b}	6.30 ± 0.58^{a}	47.10 ± 3.77^{a}
T5: with Zn and ZTB28 inoculation	16.59 ± 0.90^{a}	52.96 ± 3.04^{a}	17.67 ± 1.23^{a}	6.67 ± 1.15^{a}	57.87 ± 3.99^{a}
T6: with Zn and ZTB29 inoculation	13.85 ± 1.10^{ab}	50.23 ± 1.94^{a}	14.33 ± 1.08^{b}	5.30 ± 1.15^{a}	48.67 ± 4.26^{a}
CD at 5%	2.21	4.42	2.21	2.01	6.73
CV%	14.08	7.97	13.61	28.93	12.44

Data are recorded after 30 days of germination; data is presented as means of 4 replicates ± SD (standard deviation). The Mean value followed by same letter in column of each treatment is not significant difference at $p = 0.05$ by Tukey–Kramer HSD test.

Table 6: In vitro studies on the effect of ZTB on stress related enzymes of maize seedling under Zn stress conditions (1,000 mg Zn /kg planting mixture).

Treatment details	SOD (unit/mg) fresh weight	POD (µmole/min/g)	PAL (µmole/min/g)	Catalase (µmole/min/g)	PPO (µmole/min/g)
T1: control without Zn and ZTB inoculation	0.21 ± 0.02f	1.80 ± 0.18^{g}	0.0203 ± 0.002^{fg}	18.50 ± 0.41^{d}	0.0127 ± 0.001^{d}
T2: control with Zn and without ZTB inoculation	0.27 ± 0.02^{ab}	1.95 ± 0.30^{ab}	0.0213 ± 0.001^{ab}	19.23 ± 0.25^{a}	0.0141 ± 0.001^{c}
T3: with Zn and ZTB15 inoculation	0.36 ± 0.03^{cde}	2.82 ± 0.20^{bc}	0.0233 ± 0.006^{g}	20.92 ± 1.95^{cd}	0.0170 ± 0.002^{a}
T4: with Zn and ZTB24 inoculation	0.39 ± 0.03^{bc}	2.27 ± 0.25^{ef}	0.0283 ± 0.002^{cdef}	22.58 ± 1.26^{c}	0.0163 ± 0.002^{b}
T5: with Zn and ZTB28 inoculation	0.33 ± 0.03^{def}	2.20 ± 0.25^{ef}	0.0314 ± 0.001^{bc}	21.17 ± 2.05^{cd}	0.0174 ± 0.001^{a}
T6: with Zn and ZTB29 inoculation	0.37 ± 0.03^{cd}	2.71 ± 0.25^{cd}	0.0301 ± 0.005^{cd}	26.53 ± 1.51^{ab}	0.0176 ± 0.002^{a}
CD at 5%	0.050	0.460	0.010	1.430	0.001
CV%	8.61	11.15	14.10	3.65	4.42

*Value is mean of 4 replicates. The Mean value followed by same letter in column of each treatment is not significant difference at $p = 0.05$ by Tukey–Kramer HSD test.

Table 7: In vitro studies on the effect of ZTB on Zn accumulation in maize seedling under Zn stress conditions (1,000 mg Zn /kg planting mixture).

Treatment details	Zn concentration in shoot (µg/g fresh weight)	Zn concentration in root (µg/g fresh weight)
T1: control without Zn and ZTB inoculation	65.01 ± 5.0^{d}	46.03 ± 6.5^{e}
T2: control with Zn and without ZTB inoculation	632.64 ± 6.0^{a}	487.90 ± 11.5^{a}
T3: with Zn and ZTB15 inoculation	356.28 ± 5.1^{b}	299.70 ± 10.1^{b}
T4: with Zn and ZTB24 inoculation	335.31 ± 7.6^{bc}	280.20 ± 5.5^{bc}
T5: with Zn and ZTB28 inoculation	333.12 ± 7.5^{c}	262.20 ± 7.0^{c}
T6: with Zn and ZTB29 inoculation	339.57 ± 7.1^{bc}	218.70 ± 4.45^{d}
CD at 5%	2.44	6.22
CV%	0.39	1.29

Each value is mean of 4 replicates. The Mean value followed by same letter in column of each treatment is not significant difference at $p = 0.05$ by Tukey–Kramer HSD test.

Source: https://www.nature.com/articles/s41598-020-70846-w

Exposure of biosynthesized nanoscale ZnO to *Brassica Juncea* crop plant: morphological, biochemical and molecular aspects (2020)

Table 1: Number of interactions in the binding site determined through docking between α-amylase and Zinc acetate with their respective type of interaction.

Index	Entry	Gold score. Fitness	Interacting residues	Ionic/Hydrogen bond interactions number
1	Structure2D_CID_11192 | dock1|	36.2783	Tyr155, Gln158, Lys209, Tyr238	6
2	Structure2D_CID_11192 | dock3|	36.0536	Tyr155, Gln158, Lys209, Tyr238	6
3	Structure2D_CID_11192 | dock2|	35.4436	Tyr155, Gln158, Lys209, Tyr238	6

Table 2: Effect of ZnO NPs on different crop plants.

Plants	NP Concentration in soil/water	NP size(nm)	Effects
Macrotyloma uniflorum	2–100 mg/L	50	Delayed germination time
Fagopyrum esculentum	10–2,000 mg/L	<50 nm	Decreased the biomass content
Bean	500 mg/kg	<100 nm	Reduced root growth
Soybean	500 mg/kg	<100 nm	Ceased seed production
Glycine max	2,000 and 4,000 mg/L	55–70	Genotoxic
Lettuce	10 mg/kg	41–48	Enhanced the photosynthesis and biomass
Cyamopsis tetragonoloba	10 mg/kg	67	Increased its biomass, shoot-root length, length, chlorophyll content, and total soluble leaf protein
Triticum aestivum	20 mg/L	<100 nm	Increased grain yield and increase in shoot dry weight.
***Arachis hypogaea* L.**	400 and 1000 mg/L	25–100	Improvement in the germination rate and seedling vigor index
Tomato and egg plants	1.0 mg/mL	38–46	Boost plant defence and yield
Brassica nigra	500 to 1500 mg/L	<100 nm	Reduced seed germination and seedling growth
Brassica napus	10 to 250 mg/L	155 ± 10	Chlorosis at high concentration
Brassica juncea	10–30 µg/ml	11 nm	Increased germination and chlorophyll biosynthesis rate along with low ROS production at 20 µg/ml.
			At 30 µg/ml germination rate, chlorophyll biosynthesis decreases and ROS production increases.

Source: https://www.nature.com/articles/s41598-020-65271-y

Impact of selenium, zinc and their interaction on key enzymes, grain yield, selenium, zinc concentrations, and seedling vigor of biofortified rice (2020)

Table 1 Chemical properties of experimental dry soil

No	Index	Content	Method
2	pH	5.8	Potentiometry (NYT 1377–2007)
3	Organic carbon (g/kg of soil)	38.4	Potassium dichromate volumetric method (NYT 1121–6-2006)
4	Extractable nitrogen (mg/kg of soil)	141	Universal extraction colometric method (NYT 1849–2010)
5	Extractable phosphorus (mg/kg of soil)	28.1	Universal extraction colometric method (NYT 1849–2010)
6	Extractable potassium (mg/kg of soil)	113	Universal extraction colometric method (NYT 1849–2010)
7	Total selenium (mg/kg of soil)	0.24	Fluorescence spectrophotometry (NYT1104–2006)
8	Bioavailable selenium (mg/kg of soil)	0.026	Extraction with 0.016 M potassium dihydrogen phosphate
9	Total zinc (mg/kg of soil)	2.75	(NY/T 890–2004)
10	Available zinc (mg/kg of soil)	1.48	Extraction with DTPA (diethylenetriaminepentaacetic acid)
11	Sulfur (mg/kg of soil)	2.75	Extraction with phosphate-acetic acid solution (NY/T 1121-14-2006)
12	Cadmium (mg/kg of soil)	0.13	Graphite furnace atomic absorption spectrophotometry (GB/T17141–1997)

Table 2: Treatments and Rates of zinc (Zn) and selenium (Se) nutrients soil application

No	Treatments	Zn	Se
		(mg/kg of soil)	**(mg/kg of soil)**
T1	Control	0	0
T2	Zn_{5}	5	0
T3	Zn_{10}	10	0
T4	Zn_{15}	15	0
T5	Se(1 mg/kg)	0	1
T6	Se(1 mg/kg) + Zn_{5}	5	1
T7	Se(1 mg/kg) + Zn_{10}	10	1
T8	Se(1 mg/kg) + Zn_{15}	15	1

Table 3: Total chlorophyll, carotenoids, superoxide dismutase (SOD), and catalase (CAT) activity of R725 rice genotype as affected by single selenium, zinc, and combined selenium-zinc (Se-Zn) addition

No	Treatments	Total chlorophyll content (mg/g of fresh weight)	Carotenoids (mg/g of fresh weight)	SOD (U/g of fresh weight)	CAT (nmol/g /min/g of fresh weight)
T1	Control	2.85 a	1.81 d	574.99 a	520.2 ab
T2	Zn_5	2.85 a	2.07 bc	691.11 a	555.39 a
T3	Zn_{10}	3.16 a	2.11 bc	696.00 a	590.58 a
T4	Zn_{15}	3.27 a	2.71 a	641.01 a	465.12 ab
T5	Se(1 mg/kg)	3.26 a	1.83 d	299.21 b	250.92 d
T6	Se(1 mg/kg) + Zn_5	3.25 a	2.35 bc	308.31 b	304.47 cd
T7	Se(1 mg/kg) + Zn_{10}	3.5 a	2.23 bc	318.24 b	406.98 bc
T8	Se(1 mg/kg) + Zn_{15}	3.28 a	2.49 ab	272.9 b	550.80 a
	SEm±	0.26	0.15	35.37	36.67

Data in the column with the same letter are not significantly different at the 0.05 level by least significant difference test; SEm ± stand for means of standard error

Table 4: Grain yield and total dry matter of R725 rice genotype as affected by single selenium (Se), zinc (Zn), and combined selenium-zinc (Se-Zn) addition

No	Treatments	Grain yield (g/pot)	Total dry matter (g/pot)
T1	Control	108.73 cd	221.07 b
T2	Zn_5	125.27 ab	259.67 a
T3	Zn_{10}	131.6 ab	264.84 a
T4	Zn_{15}	126.67 ab	257.63 a
T5	Se(1 mg/kg)	100.33 d	211.77 b
T6	Se(1 mg/kg) + Zn_5	119.93 bc	245.40 a
T7	Se(1 mg/kg) + Zn_{10}	124.6 ab	258.47 a
T8	Se(1 mg/kg) + Zn_{15}	133.57a	259.73 a
	SEm±	3.58	5.44

Data in the column with the same letter are not significantly different at the 0.05 level by least significant difference test; SEm ± stand for means of standard error

Table 5: Zinc concentration in different parts of grain of R725 rice genotype as affected by single selenium, zinc (Zn), and combined selenium-zinc (Se-Zn) addition

No	Treatments	Zinc concentration (mg/kg) in			
		Grain	**Husk**	**Brown rice**	**Polished rice**
T1	Control	79.82 b	43.08 bc	36.74 a	15.22 a
T2	Zn_5	70.98 b	38.28 bc	32.70 a	18.29 a
T3	Zn_{10}	77.68 b	35.97 c	41.71 a	14.61 a
T4	Zn_{15}	82.04 b	41.63 bc	40.38 a	18.99 a
T5	Se(1 mg/kg)	101.46 a	62.18 a	39.28 a	15.81 a
T6	Se(1 mg/kg) + Zn_5	84.07 ab	50.79 ab	33.28 a	15.50 a
T7	Se(1 mg/kg) + Zn_{10}	79.62 b	38.29 bc	41.33 a	17.53 a
T8	Se(1 mg/kg) + Zn_{15}	70.32 b	38.23 bc	32.09 a	17.06 a
	SEm±	5.22	3.47	2.99	1.54

Data in the column with the same letter are not significantly different at the 0.05 level by least significant difference test; SEm ± stand for means of standard error

Table 6: Selenium concentration in different parts of grain of R725 rice genotype as affected by single selenium (Se), zinc (Zn), and combined selenium-zinc (Se-Zn) addition

No	Treatments	Selenium concentration (mg/kg) in			
		Grain	**Husk**	**Brown rice**	**Polished rice**
T1	Control	0.09 c	0.051 b	0.039 d	0.028 d
T2	Zn_5	0.085 c	0.047 b	0.037 d	0.034 d
T3	Zn_{10}	0.094 c	0.053 b	0.041 d	0.036 d
T4	Zn_{15}	0.085 c	0.051 b	0.034 d	0.033 d
T5	Se(1 mg/kg)	0.59 b	0.195 a	0.400 c	0.337 c
T6	Se(1 mg/kg) + Zn_5	0.775a	0.288 a	0.487 ab	0.408 bc
T7	Se(1 mg/kg) + Zn_{10}	0.8493a	0.283 a	0.567 a	0.533 a
T8	Se(1 mg/kg) + Zn_{15}	0.716 ab	0.222 a	0.494 ab	0.448 ab
	SEm±	0.036	0.026	0.024	0.017

Data in the column with the same letter are not significantly different at the 0.05 level by least significant difference test; SEm ± stand for means of standard error

Table 7: Germination%, length of coleoptile, and shoot and root as well as plant dry weight grown from seeds of R725 rice genotype harvested from single selenium, zinc (Zn), and combined selenium-zinc (Se-Zn) treatments

No	Treatments	Germination%	Length (mm) of			Plant Dry Weight (g/30 plants)
			Coleoptile	**Shoot**	**Root**	
T1	Control	96.67ab	1.42 ab	6.84 d	8.90b	0.72 a
T2	Zn_5	96.67 ab	1.45 ab	7.47 cd	9.06 b	0.75 a
T3	Zn_{10}	94.00 b	1.36 ab	7.48 cd	8.84 b	0.72 a
T4	Zn_{15}	96.00 ab	1.62 a	8.24 bc	9.18 b	0.71 a
T5	Se(1 mg/kg)	94.00 b	1.32 b	7.25 d	8.41 b	0.66 a
T6	Se(1 mg/kg) + Zn_5	96.67 ab	1.22 b	7.30d	9.11 b	0.64 a
T7	Se(1 mg/kg) + Zn_{10}	98.67 a	1.62 a	8.50 b	10.84 a	0.71 a
T8	Se(1 mg/kg) + Zn_{15}	98.00 ab	1.36 ab	9.86 a	12.04 a	0.71 a
	SEm±	1.86	0.12	0.37	0.64	0.05

Data in the column with the same letter are not significantly different at the 0.05 level by least significant difference test; SEm ± stand for means of standard error

Source: https://link.springer.com/article/10.1007%2Fs11356-020-08202-8

Effects of exogenous zinc on the photosynthesis and carbonic anhydrase activity of millet *(Setaria italica L.)* (2020)

Table 1: Effect of exogenous zinc on the pigment content of millet leaves. Values are means ± SE (n = 3). Different letters in the same column indicate signifcant difference at the p<0.05 level by Duncan's new multiple range test. Different concentrations of Zn solution (0, 20, 40, 60, 80, and 100 mg L^{-1}) were sprayed at the seedling stage of millet and recorded as CK, Zn_1, Zn_2, Zn_3, Zn_4, and Zn_5, respectively.

Cultivar	**Treatment**	**Chl *a* [mg g-1(FM)]**	**Chl *b* [mg g-1(FM)]**	**Chl (*a*+*b*) [mg g-1(FM)]**	**Carotenoid [mg g-1(FM)]**
Zhangzagu 10	CK	9.66 ± 0.18c	3.77 ± 0.17b	13.43 ± 0.11c	1.40 ± 0.04ab
Zn1	10.13 ± 0.05d	4.07 ± 0.12cd	14.21 ± 0.17e	1.47 ± 0.04c	
Zn2	10.40 ± 0.09e	4.21 ± 0.03d	14.62 ± 0.10f	1.47 ± 0.03c	
Zn3	9.99 ± 0.07d	3.97 ± 0.11c	13.96 ± 0.04d	1.42 ± 0.01bc	
Zn4	9.35 ± 0.10b	3.47 ± 0.09a	12.82 ± 0.19b	1.36 ± 0.05ab	
Zn5	9.14 ± 0.10a	3.27 ± 0.11a	12.41 ± 0.10a	1.35 ± 0.02a	
Jingu 21	CK	7.36 ± 0.11c	2.38 ± 0.16bc	9.74 ± 0.16c	1.31 ± 0.09ab
Zn1	8.02 ± 0.12d	2.60 ± 0.32c	10.62 ± 0.25d	1.38 ± 0.13ab	
Zn2	8.36 ± 0.09e	2.95 ± 0.13d	11.32 ± 0.12e	1.42 ± 0.03b	
Zn3	7.86 ± 0.05d	2.56 ± 0.14c	10.41 ± 0.19d	1.34 ± 0.05ab	
Zn4	7.02 ± 0.09b	2.17 ± 0.07ab	9.19 ± 0.16b	1.27 ± 0.01a	
Zn5	6.66 ± 0.09a	1.95 ± 0.17a	8.61 ± 0.09a	1.26 ± 0.08a	

Table 2: Effect of exogenous zinc on photosynthetic gas-exchange parameters of millet. Values are means ± SE (n = 3). Different letters in the same column indicate signifcant difference at the p<0.05 level by Duncan's new multiple range test. Different concentrations of Zn solution (0, 20, 40, 60, 80, and 100 mg L^{-1}) were sprayed at the seedling stage of millet and recorded as CK, Zn_1, Zn_2, Zn_3, Zn_4, and Zn_5, respectively. PN – net photosynthetic rate; gs – stomatal conductance; E – transpiration rate; Ci – intercellular CO_2 concentration.

Cultivar	**Treatment**	***P*N [µmol m-2 s-1]**	***g*s [mmol m-2 s–1]**	***E* [mmol m-2 s-1]**	***C*i [µmol mol-1]**
Zhangzagu 10	CK	6.95 ± 0.13c	54.92 ± 0.56c	2.388 ± 0.051c	212.05 ± 1.05d
Zn1	7.50 ± 0.21d	56.90 ± 0.34e	2.489 ± 0.019e	195.18 ± 1.28b	
Zn2	8.07 ± 0.15e	58.24 ± 0.27f	2.555 ± 0.020f	188.22 ± 2.54a	
Zn3	7.38 ± 0.11d	56.42 ± 0.44d	2.463 ± 0.023d	203.63 ± 4.39c	
Zn4	6.51 ± 0.13b	53.71 ± 0.29b	2.314 ± 0.016b	217.23 ± 3.26e	
Zn5	6.06 ± 0.22a	52.35 ± 0.27a	2.243 ± 0.014a	223.44 ± 2.49f	
Jingu 21	CK	5.76 ± 0.13c	50.56 ± 0.84c	2.154 ± 0.071c	249.58 ± 1.33d
Zn1	6.42 ± 0.12e	53.23 ± 0.39e	2.284 ± 0.029d	221.47 ± 0.82b	
Zn2	7.04 ± 0.13f	55.02 ± 0.20f	2.365 ± 0.011e	207.34 ± 1.73a	
Zn3	6.23 ± 0.14d	52.61 ± 0.34d	2.265 ± 0.013d	234.20 ± 4.38c	
Zn4	5.11 ± 0.15b	48.05 ± 0.12b	2.037 ± 0.021b	260.70 ± 3.12e	
Zn5	4.83 ± 0.18a	46.24 ± 0.33a	1.937 ± 0.036a	267.47 ± 2.31	

Source:
https://www.researchgate.net/publication/340753868_Effects_of_exogenous_zinc_on_the_photosynthesis_and_carbonic_anhydrase_activity_of_millet_Setaria_italica_L

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)

Table 1: 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)

Table 1: 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	ZnSO4	ZnO	ZnSO4	ZnO	ZnSO4	ZnO	ZnSO4	ZnO	**ZnSO4**
	NPs		NPs		NPs		NPs		NPs	
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

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

Table 1: 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 fertilize 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		0.30	<0.0001

	9	
Fertilizer × cultivar interaction effect	0.66 2	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.

		Zn Concentration (mg Zn kg^{-1})[a]	
Fertilizer	**Cultivar**	**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

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

	Zn Uptake and Removal (µg Zn pot^{-1})[a]		
Cultivar	**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

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 (mgkg^{-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 : 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

Zinc Fertilization Under Optimum Soil Moisture Condition Improved the Aromatic Rice Productivitv (2016)

Table 1: Effect of zinc fertilization and irrigation regimes on maximum LAI

Treatments	Zni	Zn2	Znt	Znx	Zn
Shekhupura (Site 1)					
I‹	5.29	5.55	5.72	5.89	5.88
I,	5.74	5.92	6.16	6.1	6.11
I,	5.76	5.83	6.01	6.48	6.82
I,	5.82	6.06	6.98	7.24	7.3
!5	6.4	6.83	6.96	7.46	7.51
Sargodha (Site 2)					
1	3.38	3.5	3.78	3.87	3.64
z	3.57	3.69	3.87	3.92	3.96
Iz	3.96	4.28	4.58	4.86	5.14
!4	3.85	4.28	4.58	5.13	5.59
Is	4.2B	4.6	5.2	5.28	5.08

LSD (Site 1) = 0.2, LSO (Site 2) = 0.13, Zn1 (0 kg ha”’), Znt t8 kg ha”’), Znt (10 kg ha"). Zn‹ (12 kg ha”'), Zns (14 kg ha” '), I (6 irrigations), lz (8 irriga- tions), it (10 irrigations). I, (12 irrigations), Is (14 irrigations)

Table 2: Effect of zinc fertilization and irrigation regimes on LAD

Treatments	Zn,	Zn	Zn	Zn,	Zns
Shekhupura (Site 1)					
I,	2.96.45	307.5	316.39	325.54	330.94
I,	301.2	320.82	328.6	336.26	347.54
I,	313.47	330.17	339	373.88	400.55
I‹	323	346	376.1	407.86	424.83
Is	345.42	378.89	394.81	422.38	411.31
Sargodha (Site 2)					
I‹	192.6	209.57	223.97	234.06	232.49
!2	210.5	219.58	236.81	244.38	251.15
I	233.22	260.19	276.37	293.58	309.7
I,	235.43	259.37	278.72	313.69	337.61
ls	25 .93	278.89	307.86	320.72	312.97

LSD (Site 1) = 0.2. LSD (Site 2) = 0.1 3, Zn, (0 kg ha '). Znz (8 kg ha '), Znz (10 kg ha '), Zn‹ (12 kg ha-’). Zns (14 kg ha”’), I, (6 irrigaûons). Iz (8 irriga- tions), It (10 irrigations), I (12 irrigations). I (14 irrigations)

Table 3: Effect of zinc fertilization and irrigation regimes on NAR (g m^{-2} day”)

Treatments	Zn,	Zn	Zns	Zn,	Znt
Shekhupura (Site 1)					
!1	3.34	3.4	3.49	3.6	3.77
lz	3.79	3.74	3.67	3.58	3.4
I	3.86	3.64	4.06	3.67	3.66
I‹	4.6	4.53	4.37	4.15	4.18
!s	4.11	3.78	3.75	3.62	3.68
Sargodha (Site 2)					
!1	2.92	2.98	3.07	3.18	3.35

I2	3.37	3.32	3.25	3.16	2.98
3	3.44	3.22	3.64	3.25	3.24
I,	4.18	4.11	3.95	3.73	3.76
Is	3.14	3.36	3.33	3.2	3.26

LSD (Site 1) = 0.2, LS0 (Site 2) = 0.13, Zn1 (0 kg ha”'). Zne (8 kg ha“'), Znz (10 kg ha”'), Zn, (12 kg ha”'), Zns (14 kg ha-'), If (6 irrigations), lz (8 irriga- tions), Iz (10 irrigations), I‹ (12 irrigations), Is (I 4 irrigations)

Table 4: Effect of zinc fertilization and irrigation regimes on total tillers per hill

Treatments	Zn1	Zn	Zn	Zn	Zns
Shekhupura (Site 1)					
!1	14.27	14.54	15.64	16.94	18.29
2	16.34	17.56	17.58	17.57	17.18
I_3	17.42	17.66	18.43	18.37	18.8
I_4	19.03	19.42	19.62	19.81	20.19
I_5	18.95	18.5	18.77	19.1	18.92
Sargodha (Site 2)					
I,	13.55	13.76	14.19	14.59	14.85
Iz	14.69	15.2	15.58	15.86	16.41
Iz	15.79	16.32	16.53	16.88	17.21
I‹	15.81	16.46	17.43	17.87	18.04
Is	16.53	17.63	17.76	17.92	17.91

LSD (Site 1) = 0.2, LSD (Site 2) = 0.13, Zn, ÿ0 kg ha”'). Zn; (8 kg ha"), Znz (10 kg ha ’), Zn+ (12 kg ha-‘), Zns (14 kg ha” ’), I (6 irrigations), le (8 irriga- tions), I (10 irrigations), 1+ (12 irñgations), I\ (14 irrigations)

Source: https://www.cabdirect.org/cabdirect/abstract/20163306772