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Research Article

Seed nutri-priming with zinc improves germination and early seedling growth of chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) is sensitive to Zn deficiency during early establishment period of seedling growth. Seed of two chickpea genotypes, Noor-91 and Punjab were primed in aerated solution of different Zn concentrations (0.025, 0.05, 0.075 and 0.1%) using hydropriming as control. Nutri-priming with 0.025% and 0.05% Zn increased the seed germination and seedling vigor in Noor-91 and Punjab genotypes. In case of seedling emergence, response to nutria-priming with Zn varied in chickpea genotypes and seed nutria-primed with 0.05% and 0.1% Zn emerged earlier and had high energy of emergence and final emergence percentage. Likewise, seed nutri-priming with 0.05% and 0.1% Zn concentration increased seedling fresh and dry weights in Noor-91 and Punjab chickpea genotypes. Poor seedling growth was recorded for hydropriming or seed nutri-priming with 0.025% Zn treatments. A positive relationship of Zn nutri-priming with seed germination index and seedling growth traits was also found. The variable response of both genotypes to early seedling growth was due to increased seed Zn contents by different Zn nutrient-priming treatments. In conclusion, seed nutri-priming with 0.05% and 0.1% Zn can be used under field investigation especially under low soil Zn conditions.

Keywords: Zn efficiency, priming, seed vigor, seedling growth, chickpea

1. Introduction

Zn deficiency is a widespread problem in crop plants and humans worldwide. More than 30% of world's soils are low in plant-available Zn (Alloway, 2008, Rehman et al., 2012) resulting in reduced crop yield and quality of harvested produce (Cakmak, 2008). Chickpea is an important legume crop grown in marginal and rain-fed areas with soils low in available Zn, hence, crop become deficient to its deficiency during different development stages (Khan et al., 1998, 2000; Ullah et al., 2020). Improving Zn availability, especially during critical and early establishment growth period may ensure better crop development and yield under limited soil Zn supply in chickpea (Khan et al., 2000; Ullah et al., 2019). Growing seeds enriched with Zn have several agronomic benefits, including improved seedling vigor and seed viability, reduced seed rate and higher yield in Zn-deficient soils (Rengel and Graham, 1995, Rengel, 2002, Cakmak, 2008, Farooq et al. 2012). Zinc is involved in several physiological processes such as protein synthesis, cell elongation and membrane functions affecting germination and early seedling development (Cakmak, 2000; Ozturk et al. 2006). Further, high seed Zn improves crop resistance to biotic and abiotic stresses during early seedling establishment period ensuring better crop stand and ultimately yield (Marschner, 1995; Faran et al. 2019). Increased vegetative and grain yield from enhanced seed micronutrient contents have been also reviewed by Welch (1986), Ascher et al. (1994) and Ullah et al. (2020).

Seed priming is a controlled hydration process that allows pre-germination metabolic events to occur within seed without actual germination and then re-dried to original moisture for routine handling (Farooq et al., 2019). Different salts and osmotica are incorporated into the priming media for controlled hydration and lowered water potential (Farooq et al., 2009). Polyethylene glycol (PEG), potassium salts (KNO_3, K_3PO_4, KH_2PO_4, KCl), magnesium sulphate ($MgSO_4$), $CaCl_2$, $CaPHO_4$, H_2O_2, manitol and glycinebetain are some of the salts and osmotica being used for priming. Nonetheless, use of macro- and micronutrients as priming agent has increased for their efficient use in crop production (Ullah et al., 2020). For example, Ali et al. (2008) found increase in seed P contents and significant improvement in seed yield from seed primed with P. Likely increased seed Zn contents by seed priming in $ZnSO_4$ solution enhanced the maize crop yield (Harris et al., 2007).

Use of micronutrients (Zn, B, Mn) for seed treatment is an inexpensive and effective way to improve plant nutrient status. Nutrient seed priming or nutri-priming involves soaking of seeds in mineral nutrient solution and is followed by re-drying to the initial seed dry weight (Farooq et al., 2012). In this technique,

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micronutrients are used as an osmotica to improve the germination rate and early seedling growth with an increase in micronutrient status and activation of metabolic processes necessary for germination during priming (Singh, 2007, Imran et al., 2008).

Nutrient seed priming with Zn using $ZnSO_4$ has been found to improve germination, seedling emergence and subsequent crop performance in wheat (Harris et al., 2005), maize (Harris et al., 2007), chickpea (Harris et al., 2008; Ullah et al., 2019), common bean (Kaya et al., 2007), barley (Ajouri et al., 2004) and rice (Salton et al., 2001). The improved seedling performance in these crops was the result of increased Zn uptake attributable to early establishment of root system (Ajouri et al., 2004; Ullah et al., 2019). Ullah et al. (2019) found an increase in the germination, early seedling growth and seedling Zn concentration of chickpea genotypes when seeds were primed with 0.001 M Zn. However, it was also reported that chickpea seed primed with ≥ 0.01 M Zn showed toxicity and suppressed germination and seedling growth. Nevertheless, chickpea is very sensitive to Zn deficiency during early crop establishment and differential response is found in chickpea genotypes for their sensitivity to Zn deficiency (Khan et al., 1998; Ullah et al., 2020). And Zn efficiency in chickpea genotypes is related to improved uptake of Zn following its better transport from root to shoot (Khan et al., 1998; Ullah et al., 2020). Thus, at early seedling growth stage, improvement in root growth along with early establishment of root system could play an important role in nutrient acquisition including Zn. For instance, Rengel and Graham (1995) concluded that high seed Zn content has starter fertilizer effect and there must be adequate Zn content to support early seedling growth until the roots become functional for nutrient uptake under Zn-deficient condition. Further, seed Zn content may be used to explain the difference for Zn efficiency in genotypes (Rengel and Graham, 1995). As Zn is involved in auxin synthesis a regulator of cell division including radicle and coleoptile growth of seedling development (Ozturk et al. 2006) and its deficiency has been reported to restrict root growth in chickpea (Khan 1998). Likely, low or high seed Zn concentration impedes germination due to decrease gibberellic acid and zeatin levels in germinating seeds of chickpea (Atici et al. 2005). This underpins that Zn is involved in several metabolic processes related to plant development (Ali et al. 2000; Gadallah and El-Enany, 1999). Therefore, present study was conducted to determine the effect of Zn seed nutri-priming in modulation of germination and early seedling growth response in two chickpea genotypes at different Zn concentrations and very little information is available on choosing seed Zn contents as a criterion in characterizing genotypes for their Zn efficiency.

2. Materials and Methods

Seed of widely grown two chickpea cultivars viz. kabuli type Noor 91 and desi type Punjab used in this study were obtained from Pulses Research Institute, Ayub Agriculture Research Institute, Faisalabad, Pakistan. The initial seed moisture content was 11.8 and 11.6% of cv. Noor 91 and Punjab respectively (on a dry weight basis). For nutri-priming, a specified quantity of each genotype was soaked in aerated solution of 0.025, 0.05, 0.075 and 0.1% (w/v) Zn solution using $ZnSO_4$ for 10 h. Hydropriming was carried out by soaking seeds in distilled water. For each priming treatment, seed weight to solution volume ratio was kept 1:5 (w/v). After soaking period, seeds were given three surface washings with distilled water and dried closer to the original moisture level with forced air, after which they were sealed in polythene bags and stored in a refrigerator at 7±1°C until use.

2.1. Seedling vigor evaluation

2.1.1. Germination Test

Hydro-primed and nutri-primed seeds (10 each per replicate) were placed between layers of moist filter papers in petri plates at 22±2°C in an incubator (Sanyo, England). A completely randomized design with four replications was used. Germination was observed daily according to the Association of Official Seed Analysis method (AOSA, 1990) until a constant count was achieved. The time to 50% germination (T_{50}) was calculated according to the formula given by Coolbear et al. (1984):

$$T_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{n_j - n_i}$$

where N is the final germination count, n_i and n_j are cumulative numbers of seeds germinated by adjacent counts at times t_i and t_j when $n_i < N/2 < n_j$.

A seed was considered germinated on appearance of primary root from chickpea seed. Germination energy (GE) was calculated in percentage after four days of sowing. Germination index (GI) was calculated using the following formulae (Association of Official Seed Analysts, 1983):

$$GI = \frac{\text{No. of germinated seeds}}{\text{Days of first count}} + - - - - - - - + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Mean germination time (MGT) was calculated according to the equation of Ellis and Roberts (1981). On 15th day after germination, seedlings were tested for vigour evaluation. Shoot and root lengths were recorded from 5 randomly selected seedlings per replicate. The number of leaves and roots were taken as leaf and root scores respectively. The seedling's fresh weight was determined immediately after harvest whereas the dry weight was taken after drying at 70°C for 48 h.

2.1.2. Seedling mergence

Control and treated seeds were sown in 20 x 20 cm plastic trays (15 in each) containing moist sand and were placed in a growth chamber (Vindon, England) at 22±2°C, humidity 70-80%, for 12 h in 24000-26000 Lux fluorescent + incandescent light. Again, a completely randomized design with four replications was used. Emergence was observed daily according to the Association of Official Seed Analysis method (AOSA, 1990) until a constant count was achieved. The time to 50% emergence (E_{50}) was calculated according to the formulae of Coolbear et al. (1984). A seed was scored germinated on appearance of primary root from chickpea seed. Percent emergency energy (EE) was calculated in percentage after four days of sowing. Mean emergence time (MET) was calculated according to the equation of Ellis and Roberts (1981):

$$MET = \frac{\sum Dn}{\sum n}$$

Emergence index (EI) was calculated as described in the Association of Official Seed Analysts (1983). Root and shoot length, and seedling fresh and dry weights were recorded 16 days after sowing. The number of leaves and roots at harvest were designated as leaf score and root score respectively.

2.2. Statistical analysis

All data were analyzed using MS-office Excel spreadsheet by calculating standard error (SE) to compare the means. Graphical presentation was also made using MS-office excel spreadsheet.

3. Results

3.1. Seed germination and vigor

Zn Nutri-priming showed varied response for seed germination and vigor in both chickpea genotypes at different concentrations (Tables 1 and 2). Seed priming with 0.25% Zn reduced the T_{50} and MGT in Noor-91 and with 0.5% Zn in Punjab as compared with hydropriming (Table 1). The germination index was also significantly high with 0.25 and 0.5% Zn in kabuli and desi type respectively. Nonetheless, germination energy and final germination percentage were highest for Zn nutri-priming at 0.25% in both genotypes and response for FGP was similar at 0.5% for Punjab genotype (Table 1).

Highest shoot and root length, leaf and root scores were found for seeds primed with 0.25% and 0.5% Zn in both genotypes in comparison to hydro-priming and other nutri-priming treatments respectively (Table 2). However, the leaf score was similar to 0.75% Zn in desi type. Similarly, maximum seedling fresh and dry weights were recorded for Zn nutri-priming at 0.25% and 0.5% Zn in both genotypes followed by 0.5 and 0.75% in kabuli and desi genotypes respectively (Table 2).

3.2. Seedling mergence traits

Response to Zn nutri-priming for seedling emergence was different that for seed germination and vigor. Seed priming with 0.1 and 0.5% Zn substantially improved the number of seedling emerged per day and the emergence rate was high in Noor-91 and Punjab genotypes respectively. Nonetheless, rate of seedling emergence was reduced and minimum for water-soaked seeds in both genotypes (Figure 1).

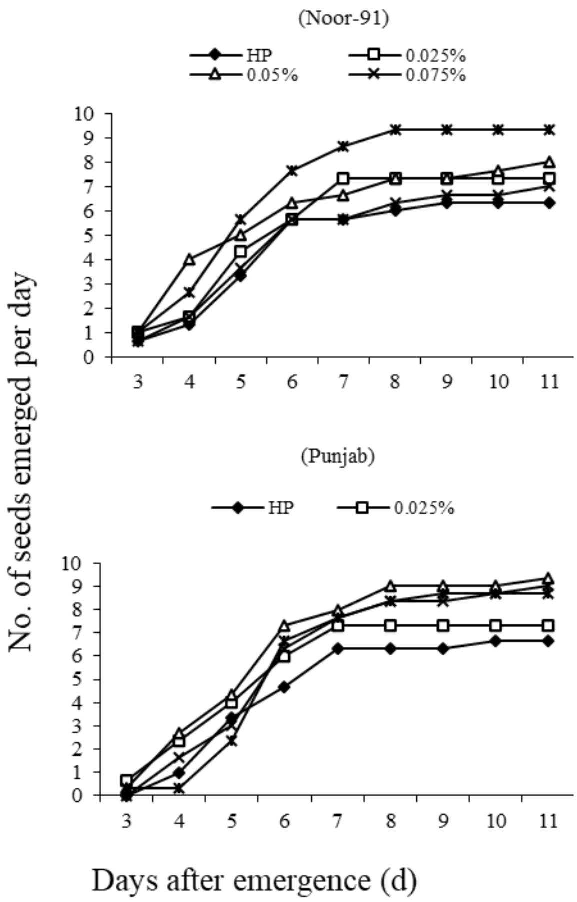

Figure 1: Influence of Zn nutri-priming on the seedling emergen two chickpea genotypes in sand filled pots

Highest EI was recorded for seeds primed with 1.0 and 0.5% Zn in chickpea genotypes kabuli and desi respectively. Response was also similar with 1.0 and 0.5% Zn with reduced E_{50} and MET in both genotypes. Nonetheless, MET values were similar for 0.1 and 0.5% Zn in Noor-91 and for 0.25% and 0.5% Zn in Punjab genotype. Similarly, highest EE and FEP were recorded for 1.0% and 0.5% Zn nutri-primed seeds in both genotypes respectively (Table 3).

Table: 1 Effect of Zn nutri-priming on seed germination of two chickpea genotypes in pteri-dishes.

Genotype/ Zn nutri-priming (%)	GI		T_{50} (days)		MGT (days)		GE (%)		FGP (%)	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
0	11.56±0.04	16.32±0.19	2.32±0.39	1.20±0.05	4.47±0.05	4.33±0.03	86.67±3.33	80.00±5.77	86.67±5.77	86.67±5.77
0.025	18.68±0.14	12.49±0.07	1.00±0.00	1.38±0.04	4.11±0.01	4.43±0.11	96.67±3.33	96.67±3.33	100.00±0.00	96.67±5.77
0.05	15.29±0.14	18.22±0.05	1.38±0.02	0.92±0.01	4.22±0.01	4.16±0.01	90.00±0.00	90.00±5.77	93.33±5.77	96.67±5.77
0.075	17.18±1.01	13.94±0.04	2.56±0.14	1.18±0.04	4.38±0.01	4.19±0.03	93.33±3.33	90.00±5.77	96.67±5.77	93.33±5.77
0.1	15.21±0.33	12.00±0.05	1.59±0.05	1.58±0.04	4.23±0.03	4.39±0.05	90.00±0.00	90.00±5.77	90.00±0.00	90.00±10.00

± SE, Standard Error

Table: 2 Effect of Zn nutri-priming on seedling vigor of two chickpea genotypes in pteri-dishes

Genotype/ Zn nutri-priming (%)	Plumule length (cm)		Radical length (cm)		Root score		Leaf score		Seedling Fresh weight (mg)		Seedling Dry weight (mg)	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
0	7.30±0.29	5.57±0.09	9.67±0.09	6.27±0.78	12.60±0.12	9.10±0.17	5.70±0.29	4.50±0.06	4810.00 ±2.89	3950.67 ±4.91	883.67±2.73	726.33±1.86
0.025	9.05±0.03	11.60±0.06	10.40±0.21	9.77±0.15	13.10±0.06	15.30±0.17	6.30±0.17	4.50±0.17	5436.00 ±11.55	4622.67 ±112.30	960.33±4.67	728.00±3.46
0.05	4.54±0.03	13.40±0.06	4.57±0.03	11.77±0.92	9.30±0.06	18.77±0.03	3.63±0.03	5.07±0.07	4231.67 ±19.63	5484.00 ±173.21	766.67±2.40	794.00±64.51
0.075	6.95±0.03	11.70±0.06	5.87±0.15	6.05±0.38	12.60±0.12	12.40±1.80	5.20±0.12	5.13±0.13	4075.67 ±8.95	4775.00 ±495.96	922.33±1.20	734.00±83.38
0.1	4.67±0.03	4.47±0.09	8.70±0.06	4.70±0.17	12.00±0.35	5.80±0.46	5.80±0.12	3.60±0.12	4047.00 ±8.08	3203.00 ±70.63	845.67±2.96	768.33±20.50

± SE, Standard Error

Shoot length was highest for 0.75% Zn in Noor-91 and for 0.5 and 1.0% Zn in Punjab. Root length was highest at 1.0% Zn while response was similar at 0.5 and 1.0% Zn in Punjab as in the case of shoot length (Table 3). Maximum leaf score was found for seed primed with 0.75 and 0.5% Zn in genotypes Noor-91 and Punjab respectively. The highest root score recorded for 1.0% Zn nutri-priming in Noor-91 was similar to 0.5% and 1.0% Zn in Punjab genotype. Seedling fresh and dry weights were increased by Zn nutri-priming with 1.0% in both genotypes followed by seed soaked in 0.75% Zn for genotype Noor-91 and 0.5% for Punjab for both fresh and dry weights (Table 4).

4. Discussion

Nutri-priming with Zn at medium (0.05%) to high (1.0%) concentration have potential to affect seedling establishment in chickpea genotypes. The variable response of two chickpea genotypes to Zn seed treatments was due to differences in inherent seed Zn contents and Zn efficiency in chickpea (Khan et al., 1998). High seed Zn contents have started fertilizing effect and explain genotyping difference for Zn efficiency (Rengel and Graham, 1995). Early germination and improvement in seedling growth from 0.05% or 0.1% Zn (Table 1, 2 and 3) was the result of high vigor levels as indicated from positive correlation between EI and seedling dry weight (Table 5 and 6).

Table: 3 Effect of Zn nutri-priming on seedling emergence of two chickpea genotypes in sand filled germination trays

Genotype/ Zn nutri-priming (%)	EI		E_{50} (days)		MET (days)		EE (%)		FEP (%)	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
0	6.03±0.68	5.62±	4.67±0.17	4.77±0.15	6.36±0.16	8.14±0.12	33.33±3.33	33.33±3.33	63.33±3.33	66.67±3.33
0.025	7.26±1.74	8.01±	3.76±0.14	4.55±0.08	6.27±0.21	7.82±0.14	43.33±8.82	40.00±0.00	73.33±6.67	73.33±3.33
0.05	8.32±0.65	8.38±	3.79±0.07	3.46±0.14	6.20±0.14	7.99±0.05	50.00±5.77	43.33±3.33	80.00±5.77	93.33±3.33
0.075	6.39±0.91	7.68±	3.75±0.12	3.90±0.06	6.33±0.06	8.22±0.04	36.67±3.33	30.00±0.00	70.00±11.55	90.00±5.77
0.1	9.31±0.57	7.26±	3.62±0.07	4.24±0.04	6.26±0.01	8.29±0.04	56.67±8.82	23.33±3.33	93.33±6.67	89.67±0.33

Table: 4 Effect of Zn nutri-priming on seedling growth of two chickpea genotypes in sand filled germination trays.

Genotype/ Zn nutri-priming (%)	Shoot length (cm)		Root length (cm)		No. of Roots		No. of Leaves		Seedling fresh weight (mg)		Seedling dry weight (mg)	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
0	5.60±0.64	5.80±0.00	6.30±0.29	7.70±0.29	10.60±0.35	8.27±0.37	5.67±0.15	6.07±0.07	3970.33 ±10.17	3192.00 ±20.55	1117.00±5.77	1201.33±28.88
0.025	5.87±0.13	6.00±0.29	7.97±0.20	8.17±1.11	11.77±0.38	10.40±0.23	4.57±0.03	6.10±0.40	4288.00 ±12.50	2776.00 ±17.01	1260.00±3.46	1028.67±30.24
0.05	7.17±0.20	8.05±0.09	10.17±0.38	11.10±0.23	12.67±0.61	16.13±0.58	6.43±0.12	7.80±0.12	5302.33 ±7.22	4005.00 ±54.04	1414.67±4.33	1321.33±44.66
0.075	8.47±0.26	7.03±0.03	10.90±0.29	8.10±0.23	12.93±0.41	14.70±0.62	7.57±0.12	6.00±0.12	5595.67 ±3.38	2776.67 ±31.14	1478.67±4.91	1152.67±27.17
0.1	6.52±0.12	8.03±0.15	12.20±0.23	11.50±0.06	14.13±0.87	16.13±0.58	6.00±0.23	6.30±0.06	5653.00 ±2.52	4642.67 ±56.10	1528.33±3.28	1376.33±13.28

± SE, Standard Error

Highest germination energy and final germination percentage was also recorded for these Zn concentrations by 100 and 96.67% in Noor-91 and Punjab genotypes respectively. The decreases in GE and FGP were observed for Zn seed treatment at 0.025% Zn concentration and hydropriming treatments in both genotypes (Tables 1 and 3). Zn pre-treatment improvement in germination could be due to earlier initiation of metabolic events during seedling growth (Shukla and Prasad, 1974). Increase in final emergence of chickpea by 0.05% Zn had been reported by Arif et al. (2007) and Ullah et al. (2019). Improvement in plumule and radical length by 0.25% or 0.05% Zn nutri-priming was the result of improved seed vigor as evident from positive correlation found between GI and root length (Tables 5 and 6). Similar increase in shoot and root lengths have been found in rice for 5 mg kg^{-1} Zn seed priming presumably through auxin action in cell enlargement and dry matter accumulation (Srinivasan and Naidu, 1986). Likely, Ullah et al. (2019) found an increase in shoot and root traits including length and secondary roots and their positive association with seedling dry weight. This might be also responsible for high seed vigor index in Zn nutri-primed treatments with favorable response and positive correlation of root length, shoot length, leaf, and root score (Table 5 and 6).

Increase in root length and root numbers in Zn nutri-primed seeds indicates the better Zn acquisition during early seedling growth when grown in Zn-deficient soils. Khan et al. (1998) described that increased root: shoot ratio might contribute to increased Zn transport to shoot in chickpea genotypes sensitive to Zn deficiency. Nonetheless, increased seedling growth attributable to Zn pre-soaking was attributed to enhanced Zn supply from endosperm to growing embryo (Srinivasan and Naidu, 1986).

Table: 5 Correlation coefficients (r) of seedling vigor and growth characteristics of two chickpea genotypes as affected by Zn nutri-priming in petri-dishes

	Seedling dry weight		Shoot length		Root length		Leaf score		Root score	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
T_{50}	0.11^{NS}	-0.19^{NS}	0.008^{NS}	-0.64**	-0.19^{NS}	-0.64**	0.21^{NS}	-0.73**	0.05^{NS}	-0.82**
MGT	-0.007^{NS}	-0.26^{NS}	-0.007^{NS}	-0.51*	-0.09^{NS}	-0.31^{NS}	0.13^{NS}	-0.46^{NS}	-0.002^{NS}	-0.64**
GI	0.42^{NS}	0.33^{NS}	0.31^{NS}	0.34^{NS}	-0.08^{NS}	0.54*	0.17^{NS}	0.52*	0.12	0.58*

($* - P < 0.1, ** - P < 0.01$ n = 4)

Table: 6 Correlation coefficients (r) of seedling vigor and growth characteristics of two chickpea genotypes as affected by Zn nutri-priming in sand filled trays

	Seedling dry weight		Shoot length		Root length		Leaf score		Root score	
	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab	Noor-91	Punjab
E_{50}	-0.77**	-0.41^{NS}	-0.33^{NS}	-0.77**	-0.73**	-0.55*	-0.55*	-0.75**	-0.23^{NS}	-0.63**
MET	-0.14^{NS}	0.39^{NS}	0.12^{NS}	0.36^{NS}	-0.16^{NS}	0.14^{NS}	-0.13^{NS}	0.26^{NS}	-0.01^{NS}	-0.15^{NS}
EI	0.61*	0.01^{NS}	-0.02^{NS}	0.49*	0.66**	0.41^{NS}	0.61*	0.61*	0.32^{NS}	0.48^{NS}

($* - P < 0.1, ** - P < 0.01$ n = 4)

Similar observations were found for wheat (Rengel and Graham, 1995), barley (Ajouri et al., 2004) and rice (Slaton et al., 2001) where increased Zn contents significantly contributed to seed germination and seedling growth particularly when grown under Zn-deficient conditions. Ullah et al. (2019) reported an increase in seedling Zn concentration owing to seed priming with Zn in chickpea. A positive correlation was found in the present study for seed vigor index and seedling dry weight in Noor-91 genotype (Table 6). Nonetheless, differential response of chickpea genotypes to Zn nutri-priming for seed vigor and seedling emergence in this study can be explained from negative interaction of priming with seed health or temperature conditions (Johnson et al., 2005). The results indicate that increasing seed Zn contents through Zn nutri-priming in chickpea cultivars is critical for better seed germination and seedling growth. Nonetheless, it also indicated that increased seed Zn content attributable to Zn nutri-priming can be used to explain the Zn efficiency in chickpea genotypes.

5. Conclusions

In crux, Zn nutri-priming with 0.05 and 0.1% can be promising to improve earlier emergence and seedling growth in chickpea under low soil Zn condition and need further investigation for physiological and biochemical basis to characterize chickpea genotypes for Zn efficiency based on seed Zn contents.

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Conflict of Interest
The authors declare no conflict of interest.

Ethics Approval
All authors have read and agreed to the published version of the manuscript.

References

Alloway, B.J., 2008. Zinc in Soils and Crop Nutrition. 2nd Edition, IZA Brussels, Belgium and IFA Paris, France.

Ajouri, A., Asgedom, H., Becker, M., 2004. Seed priming enhances germination and seedling growth of barley under conditions of P and Zn deficiency. J. Plant Nutr. Soil Sci. 167, 630-636.

Atici, Ö., G. Agar, and P. Battal. 2005. Changes in phytohormone contents in chickpea seeds germinating under lead or zinc stress. Biol. Plant. 49: 215-222.

Arif, M., Waqas, M., Nawab, K., Shahid, M., 2007. Effect of seed priming in Zn solutions on chickpea and wheat. African Crop Sci. Proc. 8, 237-240.

Ali, G., P.S. Srivastava, and M. Iqbal. 2000. Influence of cadmium and zinc on growth and photosynthesis of Bacopamonniera cultivated in vitro. Biol. Plant. 43: 599-601.

Ascher, J.S., Graham, R.D., Elliott, D.E., Scott, J.M., Jessop, R.S., 1994. Agronomic value of seed with high nutrient content. *In* Saunders, D.A., Hettel, G.P. (Ed.). Wheat in Heat-Stressed Environments: Irrigated, Dry Area and Rice-Wheat Farming Systems. CIMMYT, Mexico.

Association of Official Seed Analysts (AOSA). 1990. Rules for testing seeds. J. Seed Technol. 12, 1-112.

Association of Official Seed Analysis (AOSA). (1983). Seed vigor Testing Handbook. Contribution No. 32 to the handbook on Seed Testing. Association of Official Seed Analysis. Springfield, IL.

Cakmak, I., 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. New Phytol. 146, 185-205.

Cakmak, I., 2008. Enrichment of cereal grains with zinc: agronomic or genetic biofortification. Plant Soil. 302, 1-17.

Coolbear, P., Francis, A., Grierson, D., 1984. The effect of low temperature pre-sowing treatment under the germination performance and membrane integrity of artificially aged tomato seeds. J. Exp. Bot. 35, 1609-1617.

Ellis, R.A., Roberts, E.H., 1981. The quantification of ageing and survival in orthodox seeds. Seed Sci. Technol. 9, 373-409.

Faran, M., Farooq, M., Rehman, A., Nawaz, A., Saleem, M.K., Ali, N. and Siddiqu, K.H.M. 2019. High intrinsic seed Zn concentration improves abiotic stress tolerance in wheat. Plant Soil 437, 195–213

Farooq, M., Basra, S.M.A., Wahid, A., Khaliq, A., Kobayashi, N., 2009. Rice seed invigoration. In Lichtfouse, E. (Ed.). Organic farming, Pest control and Remediation of Soil Pollutants, Sustainable Agriculture Reviews, Springer: Berlin. pp. 137-175.

Farooq, M., Wahid, A., Siddique, K.H.M., 2012. Micronutrient application through seed treatments-a review. J. Soil Sci. Plant Nutr. 12, 125-142.

Farooq, M., M. Usman, F. Nadeem, H. Rehman, A. Wahid, S.M.A. Basra, K.H.M. Siddique. 2019. Seed priming in field crops-potential benefits, adoption and challenges. Crop and Pasture Sciences 70(9) 731-771.

Gadallah, M. A. A. and A. E. El-Enany. 1999. Role of kinetin in alleviation of copper and zinc toxicity in Lupinustermis plants. Plant Growth Reg.29: 151-160.

Harris, D., Rashid, A., Miraj, G., Arif, M., Yunas, M., 2008. ‘On-farm’ seed priming with zinc in chickpea and wheat in Pakistan. Plant Soil. 306, 3-10.

Harris, D., Rashid, A., Arif, M., Yunas, M., 2005. Alleviating micronutrient deficiencies in alkaline soils of the North-West Frontier Province of Pakistan: On-farm seed priming with zinc in wheat and chickpea. *In* Andersen, P., Tuladhar, J.K., Karki, K.B., Maskey, S.L. (Ed.). Micronutrients in South and South East Asia. Proceedings of an International Workshop held in Kathmandu, Nepal, 8–11 September, 2004. The International Centre for Integrated Mountain Development, Kathmandu, Sri Lanka. pp. 143–151.

Imran, M., Neumann, G., Romheld, V., 2004. Nutrient seed priming improves germination rate and seedling growth under submergence stress at low temperature. International Research on Food Security, Natural Resource Management and Rural Development Cuvillier Verlag Göttingen.

Johnson, S.E., Lauren, J.G., Welch, R.M., Duxbury, J.M., 2005. A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Nepal. Exp. Agric. 41, 427-448.

Kaya, M., Atak, M., Khawar, K.M., Ciftci, C.Y., Ozcan, S., 2007. Effect of pre-sowing seed treatment with zinc and foliar spray of humic acids on yield of common bean (*Phaseolus vulgaris* L.). Int. J. Agric. Biol. 7, 875-878.

Khan, H.R., McDonald, G. K., Rengel, Z., 2000. Response of chickpea genotypes to zinc fertilization under field conditions in South Australia and Pakistan. J. Plant Nutr. 23, 1517-1531.

Khan, H.R., McDonald, G. K., Rengel, Z., 1998. Chickpea genotypes differ in their sensitivity to Zn deficiency. Plant Soil. 198, 11-18.

Marschner, H., 1995. Mineral Nutrition of Higher Plants. 2nd Edition, London, Academic Press.

Ozturk, L., Yazici, M.A., Yucel, C., Torun, A., Cekic, C., Bagci, A., Ozkan, H., Braun, H.J., Sayers, Z., Cakmak, I., 2006. Concentration and localization of zinc during seed development and germination in wheat. Physiol. Plant. 128, 144-152.

Rehman, H., Aziz, T., Farooq, M., Wakeel, A., Rengel, Z., 2012. Zn nutrition in rice production systems; a review. Plant Soil. doi. 10.1007/s11104-012-1346-9.

Rengel, Z., 2002. Mineral Nutrition of Crops: Fundamental Mechanisms and Implications. CBS Publishers and Distributers, New Delhi, India.

Rengel, Z., Graham, R.D., 1995. Wheat genotypes differ in Zn efficiency when grown in chelate-buffered nutrient solution. II. Nutrient uptake. Plant Soil. 176, 317-324.

Shukla, U.C., Prasad, K.G., 1974. Ameliorative role of zinc on maize growth under alkaline soil condition. Agron. J. 66, 804-806.

Singh, M.V., 2007. Efficiency of seed treatment for ameliorating zinc deficiency in crops. In Zinc Crops, Improving Crop Production and Human Health, 24–26 May, 2007, Istanbul, Turkey.

Slaton, N.A., Wilson-Jr, C.E., Ntamatungiro, S., Norman, R.J., Boothe, D.L., 2001. Evaluation of zinc seed treatments for rice. Agron. J. 93, 152-157.

Srinivasan, P.S., Naidu, K.M., 1986. Effect of Zn on the seedling growth and micronutrient status of rice cultivars (*Oryza sativa* L.). Phillipine J. Crop Sci. 11, 47-51.

Ullah, A., Farooq, M., Rehman A., Hussain, M., Siddique, K. H. M. 2020. Zinc nutrition in chickpea (*Cicer arietinum*): a review. Crop Pasture Sci., 71, 199-218.

Ullah, A., M. Farooq, M. Hussain, R. Ahmad and A. Wakeel. 2019. Zinc seed priming improves stand establishment, tissue zinc concentration and early seedling growth of chickpea. J. Animal Plant Sci., 29: 1046-1053.

Welch, R.M., 1986. Effects of nutrient deficiencies on seed production and quality. Adv. Plant Nutr. 2, 205-247.