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Zinc Application Affects Tissue Zinc Concentration and Seed Yield of Pea (*Pisum sativum* L.)

Ejaz RAFIQUE*, Munazza YOUSRA, Muhammad MAHMOOD-UL-HASSAN, Sair SARWAR, Tauseef TABASSAM and Tayyaba K. CHOUDHARY

Land Resources Research Institute, National Agricultural Research Centre, Islamabad 45500 (Pakistan)

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ABSTRACT

A 2-year field experiment was conducted to assess the effect of applied zinc (Zn) on the seed yield of pea (*Pisum sativum* L.) and to determine the internal Zn requirement of pea with emphasis on the seed and leaves as index tissues. The experiment was carried out at two different locations (Talagang, Chakwal district and National Agricultural Research Centre (NARC), Islamabad) in the Potohar Plateau, Pakistan by growing three pea cultivars (Green feast, Climax, and Meteor). The soils were fertilized with 0, 2, 4, 8, and 16 kg Zn ha^{-1} along with recommended basal fertilization of nitrogen (N), phosphorus (P), potassium (K), and boron (B). Zinc application increased seed yield significantly for all the three cultivars. Maximum increase in the pea seed yield (2-year mean) was 21% and 15% for Green feast, 28% and 21% for Climax, and 34% and 26% for Meteor at Talagang and NARC, respectively. In all cultivars, Zn concentrations in leaves and seed increased to varying extents as a result of Zn application. Fertiliser Zn requirement for near-maximum seed yield varied from 3.2 to 5.3 kg ha^{-1} for different cultivars. Zinc concentrations of leaves and seeds appeared to be a good indicator of soil Zn availability. The critical Zn concentration range sufficient for 95% maximum yield (internal Zn requirement) was 42–53 mg kg^{-1} in the pea leaves and 45–60 mg kg^{-1} in the seeds of the three pea cultivars studied.

Key Words: calcareous soils, diagnostic criteria, vegetable crops, zinc fertiliser, zinc uptake

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Zinc (Zn) deficiency is a widespread and frequent micronutrient disorder in crops, predominantly in calcareous soils of arid and semi-arid regions worldwide (Takkar and Walker, 1993; Welch and Graham, 2002) including Pakistan (Anonymous 1998, Rafique *et al.*, 2006) because of its low solubility and high fixation under such soil conditions (Lindsay, 1979). Nearly half of the agricultural soils contain low levels of plant-available Zn (Graham and Welch, 1996), thus reducing crop yield and nutritional quality.

The soils across much of the cultivated areas in Pakistan are developed from calcareous alluvium and loess, and low in organic matter as well as many essential plant nutrients (Rashid and Ahmad, 1994). Multiple factors like free carbonates, low organic matter, high pH, and continuous nutrient removal with intensive cultivation coupled with inadequate and imbalanced fertiliser use are associated with deficiencies of nutrient in crops including Zn (Rafique *et al.*, 2006).

Pea (*Pisum sativum* L.), a cool season vegetable crop belonging to family *Leguminosae*, is one of the leading and popular vegetables in Pakistan. It is a valuable supplement to cereals and other starchy food in the human diet due to high contents of lysine and tryptophan. It is categorized as less sensitive to Zn deficiency (Alloway, 2008). However, Zn deficiency does occur in peas as Zn has many important roles in plant growth and a lack of Zn was linked to reduced seed formation (Bell and Dell, 2008). Zinc deficiency in human also appears to be a critical nutritional and health problem in the world. Challenge is being faced to increase seed/grain Zn concentration in crops to overcome widespread malnutrition especially in developing countries (Bouis and Welch, 2010). Thus, increasing Zn levels in seed could deliver more Zn to people who rely directly or indirectly on pea-derived food. Zinc application was also an effective strategy of biofortification to increase grain Zn concentration in wheat and rice (Cakmak, 2008; Hossain *et al.*, 2008; Shivay *et al.*, 2008), but information specific to pea is limited.

Foliar analysis at a particular crop growth stage is widely used as a diagnostic guide for fertilization. Whole shoots or recently matured leaves at early flowering are the tissues usually recommended for analysis

*Corresponding author. E-mail: ej.rafique@gmail.com.

(Jones *et al.*, 1991). According to Jones *et al.* (1991), seed usually is not a better index tissue for estimating the nutrient status of plants. Nevertheless, seed analyses have also been used for determining Zn supply to young plants (Rashid and Fox, 1992). Zinc concentration of seeds reflects differences among soils in their ability to supply Zn and the ability of plants to accumulate Zn (Rashid and Fox, 1992; Rafique *et al.*, 2011).

Much of the information regarding sensitivity of pea species to Zn deficiency is based on field observations, whereas corresponding experimental work is rarely reported in literature. Moreover, information concerning Zn requirement and critical concentration in plant parts of the crop is limited. Further, plant analysis diagnosing Zn concentration values published in the literature may not be appropriate for various crop genotypes grown in different agro ecological zones. Even the cultivars of the same plant species demonstrate a variable response to a specific nutrient supply/deficiency (Rengel and Romheld, 2000; Hacisalihoglu *et al.*, 2004). The objective of this study was to assess the effect of Zn application on the yield and internal Zn requirement of pea with emphasis on the seed and leaves as index tissues for determining the Zn status of crop under field conditions.

MATERIALS AND METHODS

Sites description

A 2-year (2010–2012) field experiment was conducted at two locations, *i.e.*, Talagang, Chakwal district (32°56′ N, 72°25′ E), a sandy loam Balkassar soil (coarse loamy mixed, hyper thermic Udic Haplustalf) and National Agricultural Research Centre (NARC), Islamabad (33°43′ N, 73°5′ E), a loam Nabipur soil (fine loamy mixed, hyper thermic Udic Ustochrept) in the Potohar Plateau, Pakistan. The Balkassar soil is relatively coarse-textured with lesser soil organic matter (OM), compared with Nabipur soil (Table I).

Nutrient treatments, experimental design and crop management

The experiment consisted of 45 plots, each comprised of three raised beds of 1.25-m width and 9.0-m length, arranged in split-plot design with three replications. Three pea cultivars, *i.e.*, Green feast, Climax, and Meteor were in main-plots and Zn doses, *i.e.*, 0, 2, 4, 8, and 16 kg Zn ha^{-1} as $ZnSO_4 \cdot 7H_2O$ were applied in sub-plots. Additionally, 60 kg N ha^{-1} as urea, 100 kg P_2O_5 ha^{-1} as single super phosphate, 60 kg K_2O ha^{-1} as sulphate of potash, and 1 kg B ha^{-1} as boric acid were applied as basal dose to produce normal mature plants, plus extra nutrient to provide a margin of safety in the soil until harvest. Full doses of P, K, B, Zn and one-third of N were applied at the time of sowing. Remaining amount of N was applied in two splits, *i.e.*, at apparent flowering and pod formation stages. The pea seeds were sown on both sides of beds 5 cm apart in mid October. Irrigation, weeding, and other cultural practices were done according to regular recommenda-

TABLE I

Selected initial physico-chemical characteristics of soils at two field experimental sites in the Potohar Plateau of Pakistan

Soil characteristic	Experimental site	
	Talagang	NARC[a)]
Soil series	Balkassar	Nabipur
Soil family	Coarse-loamy mixed hyper thermic Udic Haplustalf	Fine-loamy mixed hyper thermic Udic Ustochrept
Clay (%)	10	15
Silt (%)	22	45
Texture	Sandy loam	Loam
pH (1:1)	8.1	8.3
EC[b)] (1:1) (dS m^{-1})	0.40	0.54
Organic matter (g kg^{-1})	3.4	4.9
$CaCO_3$ (g kg^{-1})	24	31
NO_3^--N (mg kg^{-1})[c)]	2.2	3.0
P (mg kg^{-1})[c)]	1.3	1.9
K (mg kg^{-1})[c)]	90	120
Zn (mg kg^{-1})[c)]	0.28	0.42
B (mg kg^{-1})[d)]	0.17	0.25

[a)]National Agricultural Research Centre.
[b)]Electric conductivity.
[c)]Ammonium bicarbonate-DTPA-extractable.
[d)]Hot water-extractable.