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Short communication. Response of chickpea (*Cicer arietinum* L.) to soil zinc application

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Abstract

The response of chickpea (*Cicer arietinum*) to Zn nutrition was studied in pot experiments under natural conditions using four acid soils of northwest Spain during 2007 and 2008. Five concentrations of Zn (0, 1, 2, 4 and 8 mg Zn pot^{-1}) were added to the pots as Zn chelate. Chickpea responded to the soil Zn applications and there were highly significant differences between soils. At maturity plants fertilized with Zn had greater total dry matter production mainly due to increments in pods weight. The lowest yield (2.65 g plant^{-1}) was obtained from 0 mg Zn pot^{-1}, while the highest yield (3.52 g plant^{-1}) was recorded at 4 mg Zn pot^{-1}. The increased yields in Zn applied plants was the result of increased number of pods per plant. Furthermore, this yield component was closely correlated with the seed yield.

Additional key words: *Kabuli* type chickpea, pot experiments, yield components.

Resumen

Comunicación corta. Respuesta del garbanzo a las aplicaciones de zinc al suelo

Se estudió la respuesta del garbanzo cultivado en macetas al aire libre a las aplicaciones de Zn usando cuatro suelos del noroeste de España durante 2007 y 2008. Cinco concentraciones de Zn (0, 1, 2, 4 y 8 mg Zn maceta^{-1}) fueron añadidas a las macetas. El garbanzo respondió a las aplicaciones de Zn al suelo, existiendo diferencias altamente significativas entre los suelos. A la madurez, las plantas de las macetas fertilizadas con Zn tenían una mayor producción total, principalmente por el incremento del peso seco de las vainas. El menor rendimiento (2,65 g planta^{-1}) se obtuvo en las macetas con 0 mg Zn maceta^{-1}, mientras que el mayor rendimiento (3,52 g planta^{-1}) se alcanzó con 4 mg Zn planta^{-1}. El incremento del número de vainas por planta fue el responsable del incremento de rendimiento. El número de vainas por planta fue el componente del rendimiento más directamente correlacionado con el rendimiento en semilla por planta.

Palabras clave adicionales: componentes del rendimiento, experimento en maceta, garbanzo tipo *Kabuli*.

Chickpea (*Cicer arietinum* L.) is the principal grain legume crop grown in the Mediterranean region, being Spain a major European chickpea-producing country. Despite its importance, there are few studies on micronutrient application to chickpea. Nevertheless, widespread deficiencies in mineral nutrients in the soils, together with low moisture supply are considered the major environmental stresses leading toward yield loss in chickpea (Khan, 1998). Among the micronutrients, zinc (Zn) deficiency is perhaps the most widespread (Roy *et al*., 2006).

Chickpea is generally considered sensitive to Zn deficiency (Khan, 1998), although there are differences among varieties (Khan, 1998; Khan *et al*., 1998). In neutral to alkaline soils where chickpea is usually grown, Zn deficiency can often be encountered (Roy *et al*., 2006). Zn uptake is positively correlated with soil organic matter and negatively correlated with soil phosphorus

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Abbreviations used: CV (coefficient of variation), DW (dry weight), EC (electrical conductivity), HI (harvest index), PWR (pods weight ratio), RWR (roots weight ratio), SLWR (stems with leaves weight ratio).

(P) concentration (Hamilton *et al*., 1993). Soils with more sand and less organic matter produce lower yields related to poor utilization of Zn (Singh and Ram, 1996). In many regions, chickpea is cultivated under fallow-chickpea system; Zn uptake is low after fallow (Hamilton *et al*., 1993).

In chickpea, Zn deficiency symptoms are chlorosis of younger leaves and stipules, followed by necrosis of leaf margins and reduced shoot growth. Zn deficiency decreases yield and delays crop maturity. It also reduces water use and water use efficiency (Khan *et al*., 2004), as also root nodulation and hence nitrogen fixation (Shukla and Yadav, 1982). Zn deficiency can be easily overcome by soil application and by foliar application of Zn fertilizers (Roy *et al*., 2006).

This work was conducted to determine the effect of soil Zn applications on growth and seed yield of *Kabuli* chickpea grown in acidic soils.

Four experiments (two in 2007 and two in 2008) were carried out in the Province of León (North-West Spain) using a small-seeded *Kabuli* chickpea ecotype (cv. Pedrosillano) sown in April and harvested in August. All the experiments had five levels of Zn (0, 1, 2, 4 and 8 mg Zn per pot) and were designed as randomised blocks with three replications. Zn was added to the soil as Zn chelate and the treatments were coded as Z_0, Z_1, Z_2, Z_4 and Z_8, respectively.

Plants were grown in Armunia (Province of León, Spain) (42°35' N, 5°35' W) under natural environmental conditions in PVC pots. Pots (210 mm in diameter by 300 mm in depth) were filled with 4 kg of soil. The main physical and chemical properties of the soils are listed in Table 1. The pH values of the soils ranged from 5.6 to 6.7. The soils were collected from sites which had not been fertilized. The collection sites were located in Ribas de la Valduerna (Province of León, Spain) (local names of soils: Sotico, Regao, Housa and Era). Average temperature during crop growth was 17.1°C in 2007 and 17.0°C in 2008 and average maximum temperature 21.8°C in 2007 and 22.7°C in 2008. In all experiments, 10 seeds pot^{-1} were sown at 3 cm depth on 22 of April in 2007 and on 30 of April in 2008. One week after emergence, the seedlings were thinned to two plants per pot.

Three weeks after emergence the five Zn treatments were applied. In all pots soil moisture was maintained near field capacity by watering plants daily with deionized water. Chlorothalonil (tetrachloroisophthalonitrile) and quinosol (8-hydroxyquinoline sulphate) plus thiram (tetramethyl-thiuram sulfide) were used to reduce the disease incidence and for chickpea plant protection (Ondategui, 1996). No pests or diseases were observed.

At maturity (on 6 August in 2007 and on 14 August in 2008), all plants were harvested. Roots, stems with leaves and pods including seeds were separated, oven-dried at 80°C to a constant weight and weighed. The dry weight (DW) data were used to calculate indices

Table 1. Main physical and chemical characteristics of soils (local names) used in the experiments in two years

	2007		2008	
	Sotico	**Regao**	**Housa**	**Era**
Texture	Loam	Sandy loam	Loam	Loam
Organic matter (%)	2.1	1.9	2.3	2.3
pH (1:2.5, water)	5.6	6.7	5.9	6.2
EC (1:5, water) (dS m^{-1})	0.06	0.07	0.13	0.06
Calcium carbonate (%)	Negligible	Negligible	Negligible	Negligible
P (mg kg^{-1})	31.6	46.0	26.1	8.49
K (meq/100 g)	0.55	0.86	0.15	0.19
Ca (meq/100 g)	3.07	3.36	4.43	4.63
Mg (meq/100 g)	0.59	0.96	0.73	0.92
Na (meq/100 g)	0.09	0.12	0.02	0.06
Mn (mg kg^{-1})	9.79	24.38	17.50	16.59
Fe (mg kg^{-1})	105.0	78.24	160.00	83.74
Cu (mg kg^{-1})	1.12	1.46	1.38	1.38
Zn (mg kg^{-1})	1.26	1.94	2.03	1.53

EC: electrical conductivity.

of DW partitioning: roots weight ratio (RWR = roots DW/total DW), stems with leaves weight ratio (SLWR = stems with leaves DW/total DW), pods weight ratio (PWR = pods DW/total DW) and harvest index (HI = seed DW/total DW). Plant yield and yield components (the number of pods per plant, the number of seeds per pod and the 1,000-seed weight) were also recorded at harvest. Grain yield (g $plant^{-1}$) was calculated from the yield components.

The data were analysed by analyses of variance using the routines of SPSS version 15.0.1. Means comparison was based on Tukey test ($P < 0.01$ and $P < 0.05$) (Steel and Torrie, 1986). Different correlations were also calculated.

The experiments were conduced on acidic soils, medium in available in Zn according to Ankerman and Large (1974). This may explain why no symptoms of Zn deficiency were observed in any pot. However, chickpea responded to the soil Zn applications. Zn availability is highest at this pH range (Roy *et al.*, 2006) and Brennan *et al.* (2001) reported that the relative response to applications of Zn by chickpea is bigger than that of other crops. Plant response to soil Zn application varied with the soils concerned (Table 2). This helps to explain their influence on Zn deficiency (Loneragan and Webb, 1993).

At maturity, dry matter production was higher in Regao-2007 and Era-2008 soil types (Table 2). As the growing temperatures were similar for the experiments, the differences could be due mainly to variations in soil pH, because the texture and organic matter contents of the soils were similar (Singh and Ram, 1996). Dry matter production in Regao-2007 and Era-2008 soils increased principally because of pods weight followed by that of stems with leaves and roots. RWR and SLWR were lower in Regao-2007 and Era-2008 soils, while PWR was higher. However, HI was lower in Housa-2007 soil. This shows the strong influence of soil types on the chickpea performance, which was also recorded by Singh and Sandhu (2006).

Growth and yield characteristics were strongly affected by Zn application (Table 2). At maturity plants fertilized with Zn had a greater total dry matter production (Brennan *et al.*, 2001). Dry matter production at higher Zn supply increased mostly due to greater pod bearing. Soil Zn application increased growth (Khan *et al.*, 2000). Roots and stems DW was not significantly affected by Zn addition (Table 2). Treatments did not influence dry matter partitioning between plant organs. However, a relationship between soil Zn application and the relative dry matter production of different organs of chickpea plants was observed (Fig. 1); SLWR decreased until Z_4 ($P \leq 0.15$), while PWR and HI increased until Z_4 ($P \leq 0.15$ and $P \leq 0.20$, respectively). In the present study HI decreased when 8 mg Zn pot^{-1} were applied. Tripathi *et al.* (1997) reported that large Zn applications slightly decreased the yield.

Table 2. Dry matter production at maturity and mean yield components and seed yield of the main treatment with indication of their significance of analysis of variance and their coefficient of variation (CV)

	Roots DW (g $pant^{-1}$)	Stems with leaves DW (g $plant^{-1}$)	Pods and seeds DW (g $plant^{-1}$)	Total DW (g $plant^{-1}$)	Yield components			Yield (g $plant^{-1}$)
					Pods $plant^{-1}$	Seeds pod^{-1}	1,000-seed weight (g)	
Soil (S)	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$
— Sotico-2007	0.33	1.30	2.72	4.35	6.63	1.12	304.27	2.22
— Regao-2007	0.46	2.13	4.84	7.42	8.56	1.24	364.51	3.93
— Housa-2008	0.42	1.92	2.94	5.28	6.37	1.06	345.36	2.35
— Era-2008	0.44	1.97	4.31	6.72	7.77	1.20	373.23	3.47
Concentration of Zn application (A)	NS	NS	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.01$	NS	$P \leq 0.01$	$P \leq 0.05$
— Zn_0	0.38	1.63	3.27	5.27	5.94	1.17	374.76	2.65
— Zn_1	0.39	1.74	3.50	5.63	6.96	1.16	348.76	2.83
— Zn_2	0.41	1.87	3.79	6.06	8.04	1.18	309.96	3.04
— Zn_4	0.46	2.00	4.37	6.83	8.75	1.11	358.67	3.52
— Zn_8	0.42	1.90	3.59	5.92	7.33	1.15	342.06	2.91
Interactions								
— S × A	NS	NS	$P \leq 0.01$	$P \leq 0.01$	$P \leq 0.05$	NS	$P \leq 0.05$	$P \leq 0.01$
CV (%)	26.2	31.4	34.4	26.9	16.8	8.1	10.3	22.1

DW: dry weight. NS: not significant.

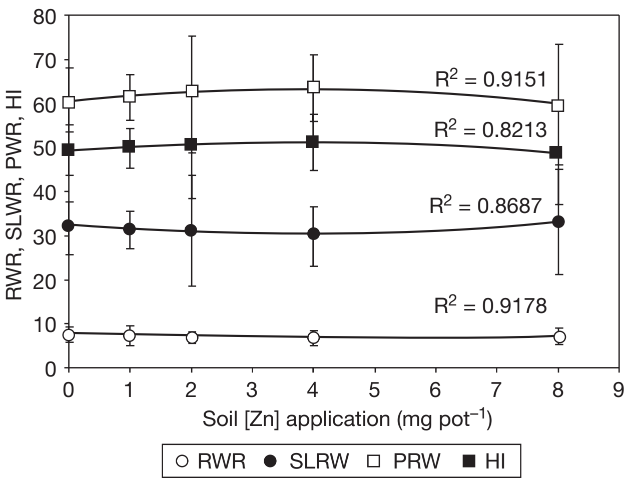

Figure 1. Relationships between soil Zn application and relative dry matter production of different organs of chickpea plants. RWR: roots weight ratio. SLWR: stems with leaves weight ratio. PWR: pot weight ratio. HI: harvest index. Represented points are treatment means.

There were also highly significant differences in pods plant^{-1} and 1,000-seed weight and significant differences in yield between Zn treatments. The smallest number of pods plant^{-1} (5.9 pods plant^{-1}) but the highest 1,000-seed weight (374.8 g) was obtained in Zn_0 treatment. The lowest yield (2.65 g plant^{-1}) was obtained when no Zn was applied. Fertilization with Zn increased chickpea yield (Brennan *et al.*, 2001). However, the increases occurred only up to Z_4 (3.52 g plant^{-1}), while Z_8 treatments caused a drop in yield (Tripathi *et al.*, 1997).

The increased yield was the result of an increased number of pods plant^{-1}, as in other leguminous plants (Valenciano *et al.*, 2007). In Zn fertilization studies using pot assays, Khan (1998) reported increased grain yield mainly by increasing pod bearing when Zn was applied in conditions of high moisture availability.

There was a highly significant interaction between soils and Zn application with respect to yield. The greatest rises in yield when Zn was applied to the soil were obtained in Regao-2008, while in Sotico-2007 soil Zn application improved them only slightly. There was a lesser response to soil Zn application in soils with lower pH values.

Stems with leaves DW was highly correlated with roots DW (0.690). Soil Zn application enhanced the growth and development of plants. Pods DW was the most influential yield component, showing the strongest correlation (0.921). Total DW was strongly correlated with seed yield (0.914) as also reported by Bhatia *et al*. (1993) and Omar and Singh (1997). According to Kumar *et al*. (2002) HI exhibited the highest significant positive correlation with the number of pods per plant (0.677) followed by seed yield (0.670). The correlation between seed yield and pods per plant showed strongest correlation with yield (Khanna-Chopra and Sinha, 1987; Chand and Singh, 1997). Pods per plant was the most important yield component, closely related (0.888) with final seed yield (Maiti and Wesche-Ebeling, 2001). However, according to Bhatia *et al*. (1993), pods per plant was highly variable yield component compared to seeds per pod, which was relatively less variable.

As conclusion, small soil Zn applications increases chickpea yield due to an increase of pods per plant, principally.

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