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Research Paper

Effect of variety and zinc application on yield, profitability, protein content and zinc and nitrogen uptake by chickpea (*Cicer arietinum*)

YASHBIR SINGH SHIVAY[1], RAJENDRA PRASAD[2] AND MADAN PAL[3]

Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field experiment was conducted during the winter seasons of 2011–12 and 2012–13 at New Delhi, to study the effect of varieties (desi types 'Pusa 372' and 'Pusa 5028' and *Kabuli* type 'Pusa 2024') and levels of zinc (Zn) (0, 2.5, 5.0 and 7.5 kg/ha) on the yields, protein content, Zn and nitrogen uptake by chickpea (*Cicer arietinum* L.). 'Pusa 372' chickpea recorded the highest grain yield (2.13 tonnes/ha), Zn concentration in grain and straw (42.9 mg/kg grain and 36.8 mg/kg straw respectively), total Zn uptake (229.0 g/ha), protein yield (480.6 kg/ha) and protein content (22.7%) in chickpea grains. *Kabuli* type 'Pusa 2024' chickpea had the lowest protein content (19.9%). Application of Zn significantly increased grain and straw yields, Zn concentration in grain and straw and its total uptake and protein yield, protein content in grain, nitrogen uptake and gross and net returns. It also increased the efficiency of applied fertilizer (NPK), being significantly highest (26.6 kg grain/kg applied NPK) with 7.5 kg Zn/ha and lowest (22.3 kg grain/kg applied NPK) with the control (no Zn).

Key words : Chickpea, Economics, Nitrogen and protein content, N uptake, Zinc concentration

Chickpea or gram is an important pulse crop and ranks third in world legume production (Ahmad *et al.,* 2005). It is one of the most important legume crops for human nutrition and has been traditionally cultivated in saline soils in arid and semi-arid regions of India (Rao *et al.,* 2002). The agronomical importance of chickpea is linked to its high protein content (25–29%) and other essential minerals, especially micronutrients (Hulse, 1991). About 49% of Indian soils are deficient in zinc (Prasad, 2006) and response to Zn application has been reported for a number of crops including chickpea (Katyal *et al.,* 2004; Tripathi *et al.,* 1997). Takkar and Nayyar (1986) reported a yield gain of 320 kg/ha in chickpea with application of 25 kg zinc sulphate/ha. However, in most studies on response to Zn application, information is restricted to yield increase and Zn uptake. In view of increasing interest in Zn malnutrition in humans, Shivay *et al.* (2008 and 2013) have reported data on Zn fortification of cereal grains due to Zn application. No attention has been given to the effect of Zn application on the protein concentration in chickpea grain, protein yield and partial factor productivity of fertilizer (NPK) applied to chickpea and therefore the present study was undertaken.

[1]**Corresponding author Email:** ysshivay@hotmail.com
[1]Principal Scientist; [2]Adjunct Professor; [3]Technical Officer, Division of Agronomy

MATERIALS AND METHODS

A field experiment was carried out during the winter (*rabi*) seasons (November–April) of 2011–12 to 2012–13 at research farm of Indian Agricultural Research Institute, New Delhi (28°38' N, 77°10' E, 228.6 m above the mean sea-level). The soil texture of experimental field was sandy clay loam and initially it had 175 kg/ha alkaline permanganate-oxidizable N, 14.7 kg/ha available P, 213 kg/ha 1 N ammonium acetate-exchangeable K and 0.47% organic carbon (Prasad *et al.,* 2006). The pH of soil was 8.1 (1:2.5 soil : water ratio) and DTPA-extractable Zn in soil was 0.69 mg/kg soil (Lindsay and Norvell, 1978). Field capacity, permanent wilting point and bulk density recorded were 23.2% (W/W), 10.4% (W/W) and 1.47 Mg/m^3 respectively, in the 0–15 cm soil depth.

The treatments combinations comprising 3 chickpea varieties, viz. 'Pusa 2024' (*kabuli*), 'Pusa 5028' and 'Pusa 372' (*desi* type) as main plots and 4 Zn levels viz. 0, 2.5, 5.0 and 7.5 kg/ha, as subplots and replicated thrice in a split-plot design were carried out. Initially, the entire field was irrigated, ploughed with tractor-drawn disc plough followed by harrowing after the soil reached to tilth conditions and leveling was done with land leveler. Recommended doses of NPK (25 kg N + 26.2 kg P + 33.3 kg K/ha) were applied uniformly to all plots. Total N, P and K were broadcast before sowing in the experimental field.

Chickpea was sown by using 75 kg seed/ha in line, with row-to-row spacing of 30 cm. The seed was placed at about 5–6 cm depth by *kera* method.

At the time of maturity the net plots (leaving 2 border rows on each side) were harvested and sun-dried for 3 days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded at 11% moisture. Straw yield was obtained by subtracting grain yield from the total biomass yield. Yield was expressed in tonnes/ha. Plant samples were collected at 10 days before of harvesting and dried in hot air oven at 60±2°C for 6 hours. The oven-dried samples were sieved by passing through 40 mesh sieve in a Macro-Wiley Mill. From each replication 0.5 g grain and straw samples were taken for chemical analysis to determine the Zn and N concentrations in chickpea grain and straw. The Zn concentrations in grain and straw samples were analysed on a di-acid [perchloric acid ($HClO_4$) + nitric acid (HNO_3) in 3:10 ratio] digests on an atomic absorption spectrophotometer (Prasad *et al.,* 2006). The N concentration in chickpea grain and straw samples were determined by modified Kjeldahl method (Prasad *et al.,* 2006). The uptake of N in chickpea grain and straw were calculated by multiplying the dry matter accumulation in grain and straw yield of chickpea with their respective concentrations expressed in kg/ha. The protein content was calculated by multiplying the N content with 6.25 as a coefficient factor (Prasad *et al.,* 2006). Cost of cultivation was calculated based on the prevailing market prices of the inputs during the respective crop seasons. Gross returns were calculated based on the grain and straw yield and their prevailing market prices during the respective crop seasons. Net returns and benefit: cost ratio were calculated.

Partial factor productivity of applied NPK (kg grain/kg applied NPK) was calculated as:

$$\text{Partial factor productivity of applied NPK} = \frac{\text{Grain yield of chickpea (kg/ha)}}{\text{Amount of NPK applied (kg/ha)}}$$

All data obtained from chickpea for 2 consecutive years of study were statistically analysed using the *F*-test the procedure given by Gomez and Gomez (1984). The critical difference (CD) values at P=0.05 were used for determine the significance of differences between means.

RESULTS AND DISCUSSION

Yield

'Pusa 372' and 'Pusa 2024' being at par grain yields, significantly out-performed 'Pusa 5028'; however, the margin was only 0.12 to 0.14 tonne/ha (Table 1). All the 3 varieties studied differed significantly in respect of straw yield. 'Pusa 372' chickpea gave significantly higher straw yield than 'Pusa 2024' and 'Pusa 5028'. Grain yield of chickpea significantly increased only when 5 kg Zn/ha was applied; there being no significant increase when the level of zinc was raised to 7.5 kg/ha. Straw yield significantly increased with an increase in level of Zn up to 7.5 kg Zn/ha. The increase in yield with zinc application was

Table 1. Effect of variety and zinc levels on grain and straw yields and Zn concentrations in grain and straw and its uptake and protein concentration and protein yield of chickpea and partial factor productivity of applied NPK (averaged over 2011–12 and 2012–13)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Zn concentration (mg/kg grain)	Zn concentration (mg/kg straw)	Total Zn uptake (g/ha) [grain + straw]	Protein content (%)	Protein yield (kg/ha)	Partial factor productivity of applied NPK (kg grain/kg applied NPK)
Varieties								
'Pusa 2024'	2.11	4.22	39.9	33.3	205.3	19.9	422.8	25.0
'Pusa 5028'	1.99	4.18	42.8	35.9	207.6	22.7	452.4	23.6
'Pusa 372'	2.13	4.33	42.9	36.8	229.0	22.6	480.6	25.2
SEm±	0.007	0.011	0.063	0.089	0.29	0.03	0.32	0.08
CD (P=0.05)	0.020	0.039	0.244	0.352	1.16	0.14	1.24	0.31
Zinc (kg/ha)								
0	1.89	3.70	36.1	29.5	155.9	20.7	391.1	22.3
2.5	2.02	4.17	40.6	33.5	196.7	21.5	435.5	24.0
5.0	2.15	4.42	43.6	37.1	232.7	22.0	493.1	25.5
7.5	2.24	4.68	47.2	41.2	271.2	22.6	473.5	26.6
SEm±	0.038	0.075	0.54	0.53	4.68	0.09	8.30	0.46
CD (P=0.05)	0.147	0.214	1.61	1.51	14.72	0.26	23.7	1.36

owing to an overall improvement in growth of plants, since Zn is a component of or is involved in enhancing the activity of a number of enzymes associated with plant growth (Prasad, 2007). Zn is also reported to reduce the incidence of *Fusarium* rot in chickpea (Gaur and Vaidya, 1983) and this leads to healthier plants.

Zinc concentration in grain and straw and its uptake

The varieties differed significantly for Zn concentrations in grain and straw (Table 1). 'Pusa 372' showed the highest Zn concentration in grain and as well as in straw, while lowest concentration in grain and straw was recorded in 'Pusa 5028'. Each increase in level (from 2.5 kg Zn/ha) significantly increased its concentration in grain and straw, highest being under 7.5 kg Zn/ha. Total Zn uptake by chickpea was the highest in 'Pusa 372', and it was significantly higher than the other 2 varieties (Table 1). The next in order was 'Pusa 5028' in the case of total Zn uptake by the crop. Total Zn uptake by chickpea increased significantly with each successive level of Zn (2.5 kg/ha) and the highest values were recorded with 7.5 kg Zn/ha.

Nitrogen concentration in grain and straw

'Pusa 372' and 'Pusa 5028' were at par and had significantly higher N concentration in grain than 'Pusa 2024' (Table 3). 'Pusa 5028' had the highest N concentration in chickpea straw, significantly higher than 'Pusa 372', this in turn had significantly higher than 'Pusa 2024'. Each increase in level of Zn from 2.5 kg/ha to 7.5 kg/ha significantly increased N concentration in chickpea grain and straw.

The 'variety × Zn level' interaction was significant for N concentration in straw and showed that in case no Zn (control) and 2.5 kg Zn/ha treatments, the chickpea varieties under study were in the order of 'Pusa 5028' > 'Pusa 372' > 'Pusa 2024' (Table 4). However, at 7.5 kg Zn/ha, 'Pusa 5028' and 'Pusa 372' were at par and recorded significantly higher N content in straw than 'Pusa 2024' (Table 5).

Protein concentration in grain and straw

'Pusa 372' and 'Pusa 5028' were at par and contained significantly more protein than 'Pusa 2024' (Table 1). However, variety 'Pusa 372', showed significantly higher

Table 2. Interaction between variety and zinc levels on protein content (%) in chickpea grain (averaged over 2011–12 and 2012–13)

Treatment	Zn (kg/ha)			
Varieties	0	2.5	5.0	7.5
'Pusa 2024' (*Kabuli*)	18.5	19.7	20.2	21.2
'Pusa 5028'	21.5	22.5	23.0	23.6
'Pusa 372'	22.0	22.4	22.8	23.1
SEm±	0.16			
CD (P=0.05)	0.47			

Table 4. Interaction between variety and zinc levels on nitrogen concentration (%) in chickpea grain (averaged over 2011–12 and 2012–13)

Treatment	Zn (kg/ha)			
Varieties	0	2.5	5.0	7.5
'Pusa 2024' (*Kabuli*)	2.95	3.15	3.24	3.39
'Pusa 5028'	3.45	3.59	3.68	3.77
'Pusa 372'	3.52	3.58	3.64	3.69
SEm±	0.027			
CD (P=0.05)	0.080			

Table 3. Effect of variety and zinc levels nitrogen concentration in grain and straw and nitrogen uptake in grain, straw and total nitrogen uptake in chickpea crop (averaged over 2011–12 and 2012–2013)

Treatment	N concentration in grain (%)	N concentration in straw (%)	N uptake in grain (kg/ha)	N uptake in straw (kg/ha)	Total N uptake (kg/ha) [grain + straw]
Varieties					
'Pusa 2024' (*Kabuli*)	3.18	0.67	67.8	28.2	95.9
'Pusa 5028'	3.62	0.92	72.3	38.4	110.7
'Pusa 372'	3.61	0.84	76.9	36.6	113.5
SE±	0.008	0.009	0.23	0.10	0.17
CD (P=0.05)	0.031	0.034	0.89	0.41	0.66
Zinc (kg/ha)					
0	3.31	0.71	62.5	25.9	88.7
2.5	3.45	0.78	69.6	32.5	102.2
5.0	3.53	0.86	76.0	37.6	113.4
7.5	3.64-3	0.89	81.2	41.6	122.8
SEm±	0.015	0.007	1.18	0.92	2.26
CD (P=0.05)	0.043	0.020	3.37	2.63	6.46

protein yield than 'Pusa 5028', which showed significantly more protein than variety 'Pusa 2024'. An increase in level of Zn from 2.5 kg/ha to 7.0 kg Zn/ha significantly increased protein content in grain as well as protein yield. Zn is reported to be associated with protein synthesis in plants (Price *et al.,* 1972) and, therefore, Zn application on a Zn deficient soil, as in the present study, increased protein concentration in grain and protein yield.

The interaction of variety and Zn level in respect of protein concentration in grain was significant and in case of no zinc fertilizer all the 3 varieties were in the order of 'Pusa 372' > 'Pusa 5028' > 'Pusa 2024'. However, when zinc was applied, 'Pusa 372' and 'Pusa 5028' were at par and contained significantly more protein than 'Pusa 2024' (Table 2).

Nitrogen uptake

Nitrogen uptake in grain as well as total N uptake by chickpea was the highest in 'Pusa 372' significantly higher than 'Pusa 5028', which had significantly higher N uptake than 'Pusa 2024'. The variety 'Pusa 5028', showed the highest N uptake, being significantly more than 'Pusa 372', which recorded significantly higher than 'Pusa 2024' (Table 3). Successive increase in level of Zn from 2.5 kg/ha to 7.5 kg/ha significantly increased N uptake in grain, straw and total N uptake by chickpea.

Table 5. Interaction between variety and zinc levels on nitrogen concentration (%) in chickpea straw (averaged 2011–12 and 2012–13)

Treatment	*Zn (kg/ha)*			
Varieties	0	2.5	5.0	7.5
'Pusa 2024' (*Kabuli*)	0.57	0.64	0.71	0.75
'Pusa 5028'	0.85	0.90	0.95	0.98
'Pusa 372'	0.70	0.81	0.91	0.96
SEm±	0.012			
CD (P=0.05)	0.035			

Partial factor productivity of applied NPK

'Pusa 372' and 'Pusa 2024' varieties were at par in terms of partial factor productivity and showed significantly more efficiency of applied fertilizer (NPK) than 'Pusa 5028' (Table 1). An increase level of Zn 2.5 kg/ha to 5.0 kg Zn/ha significantly increased the efficiency of applied fertilizer (NPK) and then it remained at par with 7.5 kg Zn/ha (Table 1). Increased yield with Zn application also increased partial productivity (PPF) of fertilizer (NPK) applied. A positive 'Zn × N' interaction was reported by Lakshmanan *et al.* (2005) in rice.

Economics

'Pusa 372' and 'Pusa 2024' were at par and gave significantly more gross and net returns than 'Pusa 5028'; however, in respect of benefit: cost ratio, these 3 varieties were in order of 'Pusa 372' > 'Pusa 202' > 'Pusa 5028' (Table 6). Zn application was profitable and gross and net returns as well as benefit: cost ratio with 5 kg Zn/ha was at par with 7.5 kg Zn/ha, and significantly more than 2.5 kg Zn/ha.

'Pusa 372' is still the best chickpea variety from the grain yield, protein concentration, protein yield and net profit. No wonder it is the farmers' choice and widely cultivated. It responded well to zinc application. In net profit, it was at par with *kabuli* type 'Pusa 2024' and superior to 'Pusa 5028'.

Thus growing of 'Pusa 372' chickpea variety in conjunction with application of 5.0 kg Zn/ha is most efficient for increased productivity, nutrient-use efficiency and nutrition quality of the chickpea.

Table 6. Effect of variety and zinc levels on economics of chickpea (averaged over 2011–12 and 2012–13)

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Varieties				
'Pusa 2024' (*Kabuli*)	27.2	77.1	49.9	1.83
'Pusa 5028'	27.2	73.4	46.2	1.69
'Pusa 372'	27.2	77.8	50.6	1.86
SEm±	-	0.20	0.20	0.006
CD (P=0.05)	-	0.76	0.76	0.024
Zinc (kg/ha)				
0	26.7	68.6	41.9	1.57
2.5	27.1	74.4	47.3	1.74
5.0	27.4	78.9	51.5	1.88
7.5	27.7	82.6	54.9	1.98
SEm±	-	1.35	1.35	0.048
CD (P=0.05)	-	3.87	3.87	0.137

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