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Genetic Variability for Zinc Use Efficiency in Chickpea as Influenced by Zinc Fertilization

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Abstract

Zinc deficiency is the major problem in chickpea production when grown on highly permeable light textured soils, low in organic matter content and continuously cropped with rice. A field experiment was conducted for two crop years (2011-12 & 2012-13) at the Indian Agricultural Research Institute, New Delhi to study the effect of variety and zinc (Zn) application on the grain yield, Zn uptake and Zn use efficiency in chickpea. In general, Pusa 372 out-performed Pusa 2024 and Pusa 5028 in growth characters, grain yield, Zn uptake and physiological efficiency of Zn applied. Chickpea variety Pusa 372 recorded 2.13 t ha^{-1} grain yield which was 0.71 and 7.04% higher compared to Pusa 2024 and Pusa 5028 (based on mean of 2 years). Similar results were also observed with straw yield of chickpea. From the viewpoint of Zn concentration in grain and its biofortification, Pusa 5028 appears promising especially at the highest level of Zn (7.5 kg Zn ha^{-1}); in the second year of study it recorded the highest Zn concentration of 50.1 mg Zn kg^{-1} grain. Each successive increase in the application of Zn from 2.5 to 7.5 kg ha^{-1} also increased the grain as well as straw yields of chickpea; however the significantly highest grain yield (2.24 t ha^{-1}, mean of 2 years) was recorded with application of 7.5 kg Zn ha^{-1} which was 18.52, 10.89 and 4.19% higher compared to 0, 2.5 and 5.0 kg Zn ha^{-1} respectively.

1. Introduction

Zinc (Zn) has now emerged as an important micronutrient malnutrition problem globally, especially in the developing countries (WHO, 2002; Hotz and Brown, 2004; IFA, 2007). Zn malnutrition and deficiency leads to diarrhea in infants, dwarfism in adolescents (Cakmak et al., 1999; Fisher et al., 2009). Zn malnutrition is more prevalent in Asian countries, where cereals are staple food (Cakmak, 2008 and Prasad, 2009). Cereals not only contain lesser amounts of Zn but also contain phytates, which reduce the bioavailability of Zn (Welch and Graham, 2004). Pulses (food legumes), such as chickpea are an important source of protein in a vegetarian diet, especially in India, where a large part of population is vegetarian and protein malnutrition is rampant (Prasad, 2003). Chickpea (*Cicer arietinum* L.) is the world's third important food legume. It is currently grown on 11.5 mha, with 96% area in the developing countries. South and south-east Asia contributes about 81% of the global chickpea production (http://www.icrisat.org/crop-chickpea.htm). Pulses not only supply protein but are also richer in Zn than cereals (Hemalatha et al., 2007). The present study was therefore conducted to study the effect of variety and Zn application on the yield attributes, yield, and Zn concentration in grain and Zn uptake by chickpea.

2. Materials and Methods

The field experiments were conducted at the research farm of IARI, New Delhi, India (28°38′N latitude and 77°10′E longitude, 228.6 msl) during November-April of 2011-12 and 2012-13 on a sandy clay-loam soil (Ustochrept). To avoid residual effects, the experiment in 2012-13 was conducted on a separate site in the same field. The soil of the field had 175 kg ha^{-1} alkaline permanganate oxidizable nitrogen (N) (Subbiah and Asija, 1956), 14.7 kg ha^{-1} available phosphorus (P) (Olsen et al., 1954), 213 kg ha^{-1} 1 *N* ammonium acetate exchangeable potassium (K) (Hanway and Heidel, 1952) and 0.47% organic carbon (C) (Walkley and Black, 1943). The pH of the soil was 8.1 (1:2.5 soil: water ratio) (Prasad et al., 2006) and diethylene triamine penta acetic acid (DTPA) extractable Zn (Lindsay and Norvell, 1978) in soil was 0.69 mg kg^{-1} soil. Zn in grain and straw samples was analyzed on a di-acid [perchloric acid ($HClO_4$)+nitric acid (HNO_3) in 3:10 ratio] digest on an atomic absorption spectrophotometer (Prasad et al., 2006).

The experiment was conducted in split plot design having three replications with three chickpea varieties (Pusa 2024, Pusa 5028, and Pusa 372) in the main plots and four Zn levels (0, 2.5, 5.0, and 7.5 kg Zn ha^{-1}) in the sub-plots. Pusa 2024 released in 2008 is kabuli type (*Cicer kabulium*) bold seeded and moderately resistant to root diseases with an average yield potential of 2.5-2.8 t ha^{-1}. Pusa 5028, a desi type (*Cicer arietinum*) released in 2012 has extra-bold seed with about 2.2-2.5 t ha^{-1} potential yield. Pusa 372 also desi type first late sown (released in 1993) has yield potential of 1.8-2.2 t ha^{-1}. It is moderately resistant to root disease and also input responsive.

At final ploughing 25 kg N as prilled urea, 26.2 kg P ha^{-1} as single superphosphate and 33 kg K ha^{-1} as muriate of potash were applied. Chickpea was sown at the seed rate of 75 kg ha^{-1} at 30×6 cm^2. The main plot size was 9.2×5.5 m^2, while the sub-plot was 5.5×2.0 m^2.

Agronomic efficiency (AE), recovery efficiency (RE), physiological efficiency (PE) and Zn harvest index (ZnHI) of applied Zn were computed using the following expressions as suggested by Dobermann (2005) and Shivay et al. (2010);

$$AE = (Y_{Zn} - Y_{Pu}) / Zn_a$$

$$RE = [(U_{Zn} - U_{Pu}) / Zn_a] \times 100$$

$$PE = (Y_{Zn} - Y_{Pu}) / (U_{Zn} - U_{Pu})$$

$$ZnHI = GU_{Zn} / U_{Zn}$$

wherein, Y_{Zn} and U_{Zn} refer to the grain yield (kg ha^{-1}) and total Zn uptake (kg ha^{-1}), respectively, of chickpea in Zn applied plots; Y_{Pu} and U_{Pu} refer to the grain yield (kg ha^{-1}) and total Zn uptake (kg ha^{-1}), respectively, of chickpea in PU (no Zn) applied plots; Zn_a refers to the Zn applied (kg ha^{-1}); GU_{Zn} refers to Zn uptake (kg ha^{-1}) in grain.

Data were statistically analyzed using the *F*-test given by Gomez and Gomez (1984). LSD values at p=0.05 were used to determine the significance of differences between treatment means.

3. Results and Discussion

3.1. Yield attributes

In both the years of study, Pusa 372 produced the most pods $plant^{-1}$ and grains pod^{-1}, significantly more than Pusa 2024, which in turn produced more than Pusa 5028 (Table 1). However, Pusa 5028 recorded the highest grain weight $plant^{-1}$, significantly more than Pusa 2024, which in turn had significantly heavier pods than Pusa 372. The grain weight $plant^{-1}$ of Pusa 5028 was 1.6 times of Pusa 372. In both the years of study, each successive level (2.5 kg Zn ha^{-1}) of Zn application up to 7.5 kg Zn ha^{-1} increased the number of pods $plant^{-1}$, however, grains pod^{-1} was not significantly affected by Zn application. Similarly, in both the years of study, each successive level (2.5 kg Zn ha^{-1}) of Zn application up to 7.5 kg ha^{-1} increased the grain weight $plant^{-1}$.

3.2. Yield

In both the years of study, Pusa 2024 and Pusa 372 were at par and produced significantly more grain than Pusa 5028, while Pusa 372 produced significantly more straw than Pusa 2024 and Pusa 5028, which were at par (Table 2). The 3 varieties in the present study were selected so as to provide a wide variability in grain size, colour of grain and yield. Pusa 372 had most pods $pant^{-1}$ and grains pod^{-1}, but had lightest brown colour grains. It is an old established popular variety of chickpea in India and in the present study outperformed the other two varieties. kabuli type (white grained) Pusa 2024 was next to Pusa 372 in pods $plant^{-1}$ and grains pod^{-1} but had heavier grains, almost twice that in Pusa 372. In grain yield it was on par with Pusa 372. Pusa 5028 had the boldest brown colour grains but the least pods $plant^{-1}$ and grains pod^{-1} and gave significantly lesser grain yield than Pusa 372 and Pusa 5028.

In 2011-12 zinc application significantly increased the grain

Table 1: Effect of variety and zinc levels on yield attributes of chickpea

Treatment	Pods $plant^{-1}$		Grains pod^{-1}		Grain weight (g) $plant^{-1}$	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Varieties						
Pusa 2024	58.9	57.5	1.42	1.37	17.7	17.0
Pusa 5028	57.5	56.1	1.27	1.18	19.9	19.2
Pusa 372	68.0	66.6	1.57	1.48	12.1	11.4
SEm±	0.08	0.08	0.008	0.02	0.008	0.005
LSD (p=0.05)	0.31	0.31	0.033	0.09	0.030	0.019
Zinc levels (kg ha^{-1})						
0	56.4	55.0	1.37	1.27	14.4	13.7
2.5	60.3	58.9	1.43	1.39	15.9	15.2
5.0	63.3	61.9	143	1.33	17.4	16.6
7.5	65.9	64.5	1.47	1.37	18.6	17.9
SEm±	0.81	0.81	0.036	0.04	0.382	0.383
LSD (p=0.05)	2.42	2.42	NS	NS	1.136	1.139

yield of chickpea only when 5 kg Zn ha^{-1} was applied; there being no significant increase when the level of Zn was increased to 7.5 kg Zn ha^{-1}. In 2012-13 a significant increase in the grain yield of chickpea was recorded even with an application of 2.5 kg Zn ha^{-1} and a further significant increase, when the level of Zn was raised to 5 kg Zn ha^{-1}; there being no significant increase when the level of Zn was raised to 7.5 kg Zn ha^{-1}.

As regards straw, in 2011-12 a significant increase in yield was recorded with an application of 2.5 kg Zn ha^{-1}, but a further significant increase was recorded only when the level of Zn was increased to 7.5 kg Zn ha^{-1}. In 2012-13 a significant increase in straw yield was recorded with each successive level of 2.5 kg Zn ha^{-1} up to 7.5 kg Zn ha^{-1}. Zn application significantly improved yield attributes, grain and straw yield, Zn concentration in grain and straw and a positive response in most characters studied was obtained up to 7.5 kg Zn ha^{-1} except in grain yield, where it was restricted up to 5 kg Zn ha^{-1}. The present study thus brings out that Zn application not only increases the grain yield in chickpea but as leads to Zn fortification of grains. Pathak et al. (2012) have reported an increase in grain yield of chickpea due to Zn application. This study is the first report on agronomic fortification of chickpea grains with Zn. We have earlier reported Zn fortification of rice and wheat grains due to Zn application (Shivay et al., 2008).

3.3. Zinc concentration

The varieties differed significantly in grain Zn concentration (Table 3). In 2011-12, Pusa 372 recorded the highest Zn concentration in grain and Pusa 5028 the lowest, while in 2012-13, Pusa 5028 recorded the highest Zn concentration in grain and Pusa 2024 the lowest. However, the range of variation in Zn concentration in chickpea grain was narrow; it was 43.8 to 44.9 mg kg^{-1} in 2011-12 and 36 to 42.2 mg kg^{-1} in 2012-13. Each successive level (2.5 kg ha^{-1}) of Zn application significantly increased Zn concentration in chickpea grain and straw and the highest Zn concentration of 50.1 mg Zn kg^{-1} grain was obtained at 7.5 kg Zn ha^{-1}. The variety×level interaction was significant in 2012-13 and showed that in no Zn (check) and at 2.5 kg Zn ha^{-1} Zn concentration in Pusa 372 and Pusa 5028 were at par and had significantly higher Zn concentration than Pusa 2024. However, at 5 or 7.5 kg Zn ha^{-1} Pusa 5028 had highest Zn concentration in grain, while Pusa 2024 had the lowest; Pusa 372 was in between (Table 4).

In both the years of study each successive level (2.5 kg Zn ha^{-1}) of Zn application increased Zn concentration in chickpea straw up to 7.5 kg Zn ha^{-1} (Table 3). Zn concentration in chickpea grain increased from 38.6 mg kg^{-1} in no Zn (check) to 48.4 mg kg^{-1} with an application of 7.5 kg Zn ha^{-1}; the values in 2012-13 were 33.6 and 45.9 mg Zn kg^{-1} straw for no Zn (check) and 7.5 kg Zn ha^{-1}, respectively.

3.4. Zinc uptake

Zn uptake in grain, straw and total Zn uptake by chickpea was the highest in Pusa 372, significantly higher than the other two varieties (Table 5). The next in order was Pusa 5028 in the case of Zn uptake by grain and total Zn uptake by the crop. In the case of straw, however, Pusa 5028 was inferior to Pusa 2024. Pusa 372 had the highest Zn concentration in grain and

Table 2: Effect of variety and zinc levels on yield of chickpea

Treatment	Grain (t ha^{-1})		Straw (t ha^{-1})	
	2011-12	2012-13	2011-12	2012-13
Varieties				
Pusa 2024 (kabuli)	2.19	2.04	4.38	4.06
Pusa 5028	2.07	1.91	4.34	4.02
Pusa 372	2.21	2.05	4.49	4.17
SEm±	0.008	0.006	0.011	0.010
LSD (*p*=0.05)	0.030	0.025	0.039	0.0.38
Zinc levels (kg ha^{-1})				
0	1.97	1.81	3.86	3.54
2.5	2.10	1.94	4.34	4.01
5.0	2.23	2.07	4.58	4.26
7.5	2.32	2.16	4.84	4.52
SEm±	0.046	0.031	0.071	0.081
LSD (*p*=0.05)	0.138	0.092	0.211	0.240

Table 3: Effect of variety and zinc levels on zinc concentrations in chickpea grain and straw

Treatment	Grain (mg kg^{-1})		Straw (mg kg^{-1})	
	2011-12	2012-13	2011-12	2012-13
Varieties				
Pusa 2024	43.8	36.0	37.0	29.5
Pusa 5028	43.4	42.2	43.3	28.4
Pusa 372	44.9	40.8	41.8	31.8
SEm±	0.10	0.025	0.17	0.008
LSD (*p*=0.05)	0.39	0.098	0.67	0.033
Zinc levels (kg ha^{-1})				
0	38.6	33.6	34.7	24.3
2.5	43.4	37.7	38.8	28.2
5.0	45.8	41.3	42.4	31.8
7.5	48.4	45.9	47.0	35.3
SEm±	0.71	0.37	0.68	0.38
LSD (*p*=0.05)	2.11	1.11	1.88	1.13

Table 4: Interaction between variety and zinc levels on Zn concentration in chickpea grain during 2012-13

Treatment	Zn levels (kg ha^{-1})			
Varieties	0	2.5	5.0	7.5
Pusa 2024	31.1	34.2	37.1	41.4
Pusa 5028	34.5	39.6	44.5	50.1
Pusa 372	35.3	39.2	42.4	46.1
SEm±	0.64			
LSD (*p*=0.05)	1.92			

recorded the highest Zn uptake in grain and straw. From the viewpoint of Zn concentration in grain Pusa 2024 was inferior to Pusa 372.

The variety×level of Zn interaction was significant for Zn concentration in grain in 2012-13 and showed that when no Zn was applied, Pusa 372 was significantly superior to other two varieties, which were at par (Table 6). However, when Zn was applied Pusa 372 and Pusa 5028 were at par and significantly superior to Pusa 2024. At all levels of Zn application, Pusa 2024 recorded the lowest Zn uptake in grain. Zn uptake in grain, straw and total Zn uptake by chickpea increased significantly with each successive level of Zn (2.5 kg ha^{-1}) and the highest values were recorded with 7.5 kg Zn ha^{-1}.

3.5. Zinc use efficiencies (ZnUE)

Agronomic efficiency (AE) and physiological efficiency (PE) (Table 7) was the highest in Pusa 2024 and the lowest in Pusa 372; Pusa 5028 was in between. Recovery efficiency (RE) was the highest in Pusa 372 in both the years of study. As regards the other two varieties, they were at par in respect of RE in 2011-12, while in 2012-13 Pusa 2024 was superior to Pusa 5028. Zn harvest index (ZnHI) was the highest in Pusa 5028 followed by Pusa 372, which in turn was superior to Pusa 2024. As regards efficiency of applied Zn, agronomic efficiency (AE) and physiological efficiency (PE) were the highest in Pusa 2024 and the lowest in Pusa 372; this was due to the low grain yield obtained by Pusa 2024 in no Zn (check) plots. These results show that Pusa 372 is a better utilizer of native soil Zn. Pusa 5028 had the best distribution of Zn to grains as judged by ZnHI.

As regards level of Zn application AE and PE were at par at 2.5 or 5.0 kg ha^{-1} and significantly higher than at 7.5 kg Zn ha^{-1}. In 2011-12 RE was the highest at 2.5 kg Zn ha^{-1}, significantly higher than at 5 or 7.5 kg Zn ha^{-1}, which were at par. In 2012-13 RE significantly declined with each successive level of Zn. The highest ZnHI was recorded with check (no Zn) and the minimum at 7.5 kg Zn ha^{-1}.

3.6. Interactions in relation to ZnUE

As regards AE, the variety×level was significant in both the years (Table 8 & 9). In 2011-12, Pusa 2024 recorded the highest AE, significantly higher than Pusa 5028, which in turn was superior to Pusa 372 at 2.5 or 5 kg Zn ha^{-1}. This was also true for 2012-13. However at 7.5 kg Zn ha^{-1} in 2011-12, Pusa 2024 and Pusa 5028 were at par and Pusa 2024 recorded significantly higher AE than Pusa 372.

The variety×level of Zn interaction was significant for RE in both the years and Pusa 372 recorded the highest RE (Table 10 & 11). At 2.5 kg Zn ha^{-1}, Pusa 372 recorded significantly higher RE than Pusa 2024 and Pusa 5028, which were at par. At 5 kg Zn ha^{-1} only Pusa 2024 recorded significantly lesser RE than Pusa 372, while at 7.5 kg Zn ha^{-1} the chickpea varieties did not significantly differ in respect of RE.

The variety×level interaction was significant for PE in both the years and Pusa 2024 recorded the highest PE at 2.5 and 5 kg Zn ha^{-1}, significantly higher than Pusa 5028, which in turn recorded significantly higher than Pusa 372 (Table 12 & 13). However at 7.5 kg Zn ha^{-1} in 2012-13, Pusa 2024 and Pusa 5028 were at par and recorded significantly higher PE than Pusa 372. The interaction between variety×level was significant in 2012-13

Table 5: Effect of variety and zinc levels on zinc uptake in chickpea grain, straw and total

Treatment	Zn uptake in grain (g ha^{-1})		Zn uptake in straw (g ha^{-1})		Total Zn uptake (g ha^{-1}) [grain+straw]	
Varieties	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Pusa 2024	81.7	73.7	133.6	121.6	215.3	195.3
Pusa 5028	90.3	81.6	127.8	115.5	218.1	197.1
Pusa 372	92.7	83.8	147.4	133.9	240.1	217.8
SEm±	0.23	0.36	0.87	0.32	0.33	0.25
LSD (*p*=0.05)	0.92	1.40	3.43	1.27	1.32	0.99
Zinc levels (kg ha^{-1})						
0	68.3	60.9	96.6	86.0	164.9	146.9
2.5	81.4	73.1	125.5	113.2	206.9	186.4
5.0	94.5	85.8	149.3	135.7	243.8	221.5
7.5	108.8	99.0	173.8	159.7	283.6	258.7
SEm±	0.77	1.93	2.51	4.03	3.47	5.88
LSD (*p*=0.05)	2.29	5.73	7.45	12.00	11.97	17.47

Table 6: Interaction between variety and zinc levels on Zn uptake in chickpea grain during 2012-13

Treatment	Zn levels (kg ha^{-1})			
Varieties	0	2.5	5.0	7.5
Pusa 2024	63.3	76.1	87.5	100.0
Pusa 5028	66.8	82.3	97.9	114.3
Pusa 372	74.9	85.8	98.2	112.1
SEm±	1.33			
LSD (*p*=0.05)	3.97			

Table 7: Effect of variety and zinc levels on zinc use-efficiencies in chickpea

Treatment	AE (kg grain increased kg^{-1} Zn applied)		CRE (%)		PE (kg grain kg^{-1} Zn uptake)		ZnHI (%)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Varieties								
Pusa 2024	64.0	64.0	1.57	1.48	4247.2	4308.7	38.2	35.2
Pusa 5028	53.2	52.3	1.56	1.18	3291.1	3324.8	41.4	41.4
Pusa 372	36.9	36.2	1.71	1.61	2185.0	2405.3	38.9	39.9
SEm±	1.30	0.64	0.008	0.011	103.7	112.5	0.11	0.14
LSD (p=0.05)	5.10	2.52	0.033	0.042	407.1	441.5	0.43	0.55
Zinc levels (kg ha^{-1})								
0	-	-	-	-	-	-	41.4	41.5
2.5	54.2	53.3	1.68	1.58	3503.9	3440.0	39.4	39.3
5.0	52.7	52.0	1.58	1.49	3315.0	3466.3	38.8	38.8
7.5	47.2	47.2	1.58	1.19	2904.4	3132.4	38.4	38.3
SEm±	1.18	0.76	0.026	0.025	112.4	75.4	0.55	0.34
LSD (p=0.05)	3.64	2.36	0.080	0.076	346.4	232.4	1.63	1.00

Table 8: Interaction between variety and zinc levels on Zn agronomic efficiency in chickpea during 2011-12

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	76.0	64.0	52.0
Pusa 5028	58.7	54.0	47.1
Pusa 372	28.0	40.0	42.7
SEm±	2.05		
LSD (p=0.05)	6.31		

Table 10: Interaction between variety and zinc levels on recovery efficiency of Zn in chickpea during 2011-12

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	1.54	1.52	1.64
Pusa 5028	1.63	1.54	1.51
Pusa 372	1.86	1.67	1.59
SEm±	0.045		
LSD (p=0.05)	0.138		

Table 9: Interaction between variety and zinc levels on Zn agronomic efficiency in chickpea during 2012-13

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	76.0	64.0	52.0
Pusa 5028	56.0	54.0	47.0
Pusa 372	28.0	38.0	42.7
SEm±	1.32		
LSD (p=0.05)	4.08		

Table 11: Interaction between variety and zinc levels on Zn recovery efficiency in chickpea during 2012-13

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	1.45	1.43	1.55
Pusa 5028	1.54	1.47	1.42
Pusa 372	1.75	1.57	1.50
SEm±	0.043		
LSD (p=0.05)	0.132		

Table 12: Interaction between variety and zinc levels on physiological use efficiency of Zn in chickpea during 2011-12

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	5507.7	4174.0	3060.0
Pusa 5028	3356.3	3431.0	3086.0
Pusa 372	1647.7	2340.0	2567.3
SEm±	194.7		
LSD (p=0.05)	599.9		

Table 13: Interaction between variety and zinc levels on physiological use efficiency of Zn in chickpea during 2012-13

Treatment	Zn levels (kg ha^{-1})		
Varieties	2.5	5.0	7.5
Pusa 2024	5171.0	4423.7	3331.3
Pusa 5028	3090.3	3637.7	3246.3
Pusa 372	2058.7	2337.7	2819.7
SEm±	130.6		
LSD (p=0.05)	402.5		

Table 14: Interaction between variety and zinc levels on Zn harvest index in chickpea during 2012-13

Treatment	Zn levels (kg ha^{-1})			
Varieties	0	2.5	5.0	7.5
Pusa 2024	40.5	39.0	37.6	35.6
Pusa 5028	41.7	40.7	41.5	41.7
Pusa 372	42.2	38.2	37.3	37.7
SEm±	0.58			
LSD (p=0.05)	1.37			

and showed that when no Zn was applied Pusa 372 recorded the highest ZnHI (Table 14). However, when Zn was applied at 2.5 or 5 kg Zn ha^{-1}, Pusa 5028 recorded the highest ZnHI, significantly higher than Pusa 2024 and Pusa 372. Further, when Zn was applied at 7.5 kg Zn ha^{-1} the chickpea varieties were in the following order: Pusa 5028>Pusa 372>Pusa 2024; Pusa 5028 recording the highest ZnHI.

4. Conclusion

Chickpea varieties studied differed in yielding ability and utilization of native and applied Zn. Pusa 372 outperformed other varieties in yield but had lower agronomic and physiological efficiencies of applied Zn. Chickpea responded well to Zn application and Zn biofortification is possible by Zn application.

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