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Research Paper

Application of zinc and iron for higher productivity and agronomic use efficiency of chickpea (*Cicer arietinum*) varieties

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ABSTRACT

An experiment was conducted during the winter season of 2017–18 and 2018–19 at the University of Agricultural Sciences, Dharwad, Karnataka to evaluate the effect of Zn and Fe on productivity and agronomic use efficiency of chickpea (*Cicer arietinum* L.). In this experiment, 2 varieties of chickpea were applied with Zn and Fe through foliage in the form of sulphates at different stages and also tested with the application to soil and via a seed treatment. Variety 'GBM 2' gave higher yield, Zn and Fe content in seed than 'JG 11'. However, 'JG 11' was more efficient in using native Zn and Fe, as it had shown higher Zn and Fe agronomic efficiency under all the methods compared to 'GBM 2'. Foliar application of Zn and Fe proved better method of application than soil application or seed treatment of Zn or individual application of Zn or Fe. Yield increase was 20.2 and 19.35% higher in foliar application of Zn and Fe over the control respectively, in 2017–18 and 2018–19. Foliar application of Zn with Fe recorded 22.29 and 11.30% higher Zn accumulation in seed over soil application of micronutrients in 2017–18 and 2018–19 respectively.

Key words: Agronomic efficiency, Bio-fortification, Fe, Variety, Yield, Zinc

Essentiality of Zinc (Zn) and Iron (Fe) for plants has been well established as both are essential micronutrients involved in number of essential functions. The Fe involved in the growth of pulses through enzymatic reactions, photosynthesis and higher dry-matter production and in turn it enhances the pod formation and seed setting. The Fe is also necessary for symbiotic nitrogen fixation (nitrogenase). Deficiency of Fe leads to interveinal chlorosis (yellowing of interveinal portion with dark green veins). In severe cases, the entire leaf turns brown and withered. Lesser accumulation of Zn and Fe was observed in the seed of crop which rose on the soils deficit in these micronutrients (Alloway, 2009). Further, the consumption of Zn and Fe deficit seed by human beings also create deficiency (Zn and Fe) in them.

Zinc helps in elongation of internodes, flower initiation, seed production and maturation, protein synthesis. It is one of the essential plant nutrients which plays important role in metabolic, regulatory, and developmental processes (Broadly *et al.,* 2007). The Zn deficiency led to reduction in pollen viability, changes stigmatic size, morphology and exudations and further inhibiting pollen-stigma interaction (Pandey *et al.,* 2009). The Zn deficiency is predicted to worsen due to reducing Zn levels under global climate change, intensive cropping and non application of organic manures.

In human, Fe being a co-factor for several enzymes performs basic functions and Zn is involved in normal tissue growth and hormone balance in human body. Inadequate supply of Fe leads to disability, anaemia and stunted mental growth, and Zn deficiency enhances the risk of low fertility, poor immune system and depression. For this reason, Zn and Fe deficiency issues have been attracting an increasing focus worldwide.

Production of Zn- and Fe-fortified crops has been recognized as a tool to cope with the issue of Zn and Fe deficiency. Application of Zn brought a positive effect on grain yield and seed Zn concentration, especially under Zn-deficient soils Shivay *et al.* (2014). The $ZnSO_4$ and $FeSO_4$ are the dominant form of inorganic Zn and Fe which are available for plant uptake in natural condition. Hence it is important to investigate the stage of application and method

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of application, as they influence the uptake and translocation of Zn and Fe in plants.

MATERIALS AND METHODS

The experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (15° 26'N, 75° 01' E, 678 m above mean sea-level), during the (*rabi*) winter season of 2017–18 and 2018–19 to study the effect of method of application of Zn and Fe on yield, their concentration in seed and agronomic use efficiency of these micronutrients in chickpea varieties. Organic carbon and *p*H of the soil were 0.52% and 7.4, respectively. The soil of the experimental field was clay, having fertility status of 220.0 kg available N/ha, 28.2 kg available P/ha and 384.0 kg available K/ha, 0.7 mg/kg zinc and 1.2 mg/kg Fe. The experiment was laid out in a split-plot design. Two varieties 'GBM 2' and 'JG11' of chickpea were kept in main plots and 6 application methods of Zn and Fe, viz. $Zn^- \rightarrow$ No Zn and Fe (control), $Zn^+ \rightarrow$ 0.5% $ZnSO_4$ foliar application, $Zn^- + Fe^+ \rightarrow$ 0.1% $FeSO_4$ foliar application, $Zn^+ + Fe^+ \rightarrow$ 0.5% $ZnSO_4$ and 0.1% $FeSO_4$ through foliar application, $Znsd^+ \rightarrow$ seed treatment of $ZnSO_4$ 80 g/ha, $Zns^+ + Fes^+ \rightarrow$ Soil application of 25 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ were in subplots. Gross plot was 4.5 m × 3.0 m and net plot was 3.9 m × 2.6 m. Recommended dose of nitrogen and phosphorus (25 and 50 kg/ha) was applied uniformly to all the plots in the form of diammonium phosphate and urea at the time of sowing. The distance between the rows was 30 cm and the gap between the plants in each row was 10 cm. Available nitrogen, phosphorus and potassium were estimated through alkaline permanganate method (Subbaiah and Asija, 1956), Olsen and Sommers's method (Olsen and Sommers, 1982), flame photometer method (Jackson, 1967) respectively. Available Zn and Fe (mg/kg), organic carbon (%) *p*H (1 : 2.5, soil : water) and electrical conductivity (dS/m) were measured through AAS after DTPA extraction (Lindsay and Norvell, 1978), Walkley's procedure (Walkley, 1947), Buckman's *p*H meter (Piper, 2002) and EC bridge (Jackson, 1973) respectively. At harvesting (110 days after sowing) number of pods/plant, dry weight/plant and seed yield/plant were recorded from 5 random plants from the net plot area of each plot. Grain yield was recorded from each net plot and 100 seed weight was recorded.

Agronomic efficiency (AE) of Zn and Fe was worked out as suggested by Fageria *et al.* (1990)

Data on chickpea crop of both the years were carried out standard analysis of variance (ANOVA) following standard procedures for split-plot design (Gomez and Gomez, 1984). The *F*-test was used to compare significant differences between treatment means with the least significant difference (LSD) at 5% level. Further, DMRT was used for comparison of means of parameters studied in this experiment using M stat C software. Karl Pearson's Coefficient was used for correlating yield parameters with yield.

RESULTS AND DISCUSSION

Relation between yield and yield parameters

Karl Pearson's correlation coefficient was worked out between important yield parameters, yield and Zn and Fe content in seed (Fig. 1). The correlation heat map indicated that, the association between yield and important growth, yield parameters, Zn and Fe content was linear and positive. Very strong linear association was observed between yield and seed yield/plant (0.92) and 100-seed weight (0.97). Strong correlation was observed between yield and pods/plant (0.85), dry weight/plant (0.89), Zn (0.81) and Fe (0.88) content in seed.

Varieties

There was significant difference between the varieties for growth and yield parameters (Table 1). The variety GBM 2 gave 10.03 and 15.54% higher yield than 'JG11' in 2017–18 and 2018–19, respectively. The yield of chickpea was highly dependent on number of pods/plant, seed yield/plant and 100-seed weight and recorded 0.85, 0.92 and 0.97 correlation coefficient for yield, respectively (Fig 1). The variety 'GBM 2' recorded 11.6 and 23.20% higher number of pods/plant, 7.62 and 25.44% higher seed yield/plant, 12.69 and 14.28% higher dry weight plant and 3.17 and 8.54% higher 100-seed weight than 'JG 11' in 2017–18 and 2018–19, respectively (Table 1). This difference can be attributed to genetic variation and specific physiological trait which makes certain genotypes capable to tolerate the

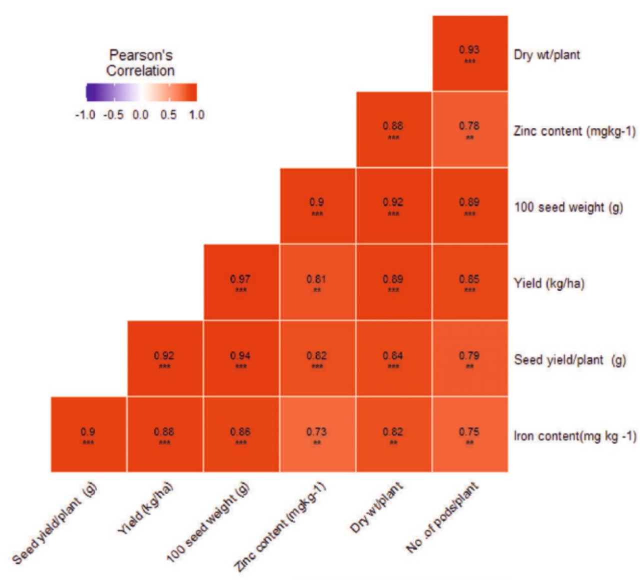

Fig. 1. Heat map showing correlation of important yield parameters, yield and Zinc and iron content in seed

Table 1. Effect of micronutrient application methods and varieties on yield and yield parameters of chickpea

Treatment	Dry-weight/plant (g)		Pods/plant		Seed yield/plant (g)		100-seed weight (g)		Seed yield (kg/ha)	
Varieties	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19
'GBM 2'	21.3 a	20.0 a	35.5 a	35.1a	12.7a	12.9 a	22.8 a	20.46 a	2,358 a	1,873 a
'JG11'	18.9 b	17.5 b	31.8 b	28.5b	11.8b	10.3 b	22.8 b	18.85 b	2,190 b	1,621 b
Application method of Zn and Fe										
Zn^-	17.8 f	17.2 de	30.9 de	24.78 e	9.4 de	9.07 e	20.2 c	18.47 de	2,048 de	1,602 de
Zn^+	21.3 b	17.9 cd	34.8 a	32.39 bcd	14.0 ab	11.99 bc	23.6 ab	20.66 ab	2,382 ab	1,870 ab
$Zn^- + Fe^+$	20.3 c	18.5 b	33.4 c	32.06 bd	12.9 b	12.69 ab	22.9 bc	20.2 a	2,340 ab	1,851 ab
$Zn^+ + Fe^+$	22.4 a	20.4 a	36.4 a	35.39 a	14.8 a	13.26 a	24.4 a	21.57 a	2,462 a	1,912 a
$Znsd^+$	19.0 d	18.2 bc	32.4 cd	32.78 ab	10.3 d	10.22 d	21.5 d	19.46 c	2,175 cd	1,581 e
$Zns^+ + Fes^+$	19.6 de	20.2 a	34.5 ab	33.44 a	12.1 bc	11.42 bc	22.3 cd	19.14 cd	2,238 bc	1,664 c

Zn^-, RDF (control); **Zn^+**, RDF + 0.5% Zn foliar application; **$Zn^- + Fe^+$**, RDF + 0.1% Fe foliar application; **$Zn^+ + Fe^+$**, RDF + 0.5% Zn and 0.1% Fe through foliar application; **$Znsd^+$,** RDF + seed treatment 5 g Zn/kg of seeds; **$Zns^+ + Fes^+$,** soil application of 25 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ **RDF**, Recommended dose of fertilizer (25 : 50 : 0 N : P_2O_5 : K_2O)

- Values with similar alphabets were non-significant with each other in the above table (Tested with Duncan's Multiple Range Test).

particular environment and gave the better yield. Varietal difference for number of pods was also observed by Hidoto *et al.* (2016).

'GBM 2' variety recorded significantly higher Zn and Fe content in grain than 'JG 11' (Table 2). The 'GBM 2' showed higher Zn content of 38.52 and 34.67 mg/kg,being 2.86 and 8.92 % higher than 'JG 11' in 2017–18 and 2018–19, respectively. 'GBM 2' showed higher 10.54 and 6.69% higher Fe content than 'JG 11' in 2017–18 and 2018–19, respectively. The variation in seed Zn and Fe content of the chickpea variety 'GBM 2' could be due to difference in physiological mechanism, seed physiology, morphology and Zn accumulation which influenced by genetic character (Norton *et al.,* 2014).

Variety 'JG 11' recorded significantly higher agronomic efficiency of Zn and Fe in 2017–18 and 2018–19 than 'GBM 2' and indicated that 'JG 11' was more responsive to Zn application than 'GBM 2' (Table 2 and Fig. 2b).

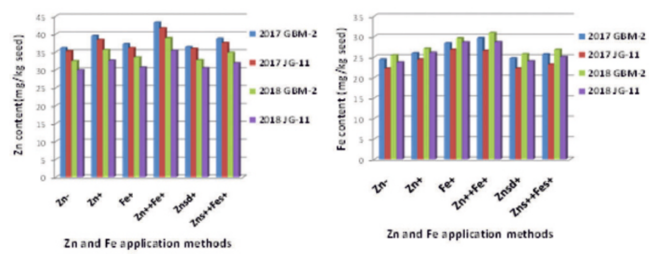

Fig. 2. Zinc and iron content of chickpea seed as influenced by micronutrient application methods and varieties

Application methods of zinc and iron

Application methods of Zn and Fe had significant effect on growth of chickpea. Foliar application of Zn and Fe re-

Table 2. Zinc and iron content of seed and agronomic efficiency of Zn and Fe as influenced by micronutrient application methods and varieties of chickpea

Treatment	Zn content (mg/kg)		Fe content (mg/kg)		Agronomic efficiency of Zn (kg/kg)		Agronomic efficiency of Fe (kg/kg)	
Varieties	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19
'GBM 2'	38.52 a	34.67 a	26.43 a	27.58 a	58.7 a	18.6 b	27.6 a	19.6 a
'JG 11'	37.47 b	31.83 b	23.91 b	25.85 b	45.2 b	31.1 a	32.2 b	34.6 b
Application method of Zn and Fe								
Zn^-	35.6 d	31.21 d	23.28 d	24.50 cd	–	–	–	–
Zn^+	38.95 b	34.10 b	25.16 c	26.56 b	33.45 b	26.85 bc	-	-
$Zn^- + Fe^+$	36.65 c	32.08 bcd	27.54 ab	29.07 a	41.4 b	31.0 b	29.2 b	24.95 b
$Zn^+ + Fe^+$	42.4 a	37.12 a	28.06 a	29.78 a	-	-	41.4 a	31.0 a
$Znsd^+$	36.15 c	31.64 cd	23.42 d	24.86 cd	158.75 a	61 a		
$Zns^+ + Fes^+$	38.1 b	33.35bc	24.10 c	25.90 bc	7.6 c	7.53 d	19 bc	25.35 b

Zn^-, RDF (control); **Zn^+**, RDF + 0.5% Zn foliar application; **$Zn^- + Fe^+$**, RDF + 0.1% Fe foliar application; **$Zn^+ + Fe^+$**, RDF + 0.5% Zn and 0.1% Fe through foliar application; **$Znsd^+$,** RDF + seed treatment 5 g Zn/kg of seeds; **$Zns^+ + Fes^+$,** soil application of 25 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ **RDF**, Recommended dose of fertilizer (25 : 50 : 0 N : P_2O_5 : K_2O)

- Values with similar alphabets were non-significant with each other in the above table (Tested with Duncan's Multiple Range Test).

sulted in significantly higher dry weight (22.4 and 20.4 g), seed yield/plant, test weight and higher yield in 2017–18 and 2018–19 than the other treatments (Table 1).

Foliar application of Zn and Fe recorded significantly higher yield than the control (20.21 and 19.35%), seed treatment of Zn (15.32 and 20.94%) and soil application of Zn and Fe (10.01 and 14.90%) in 2017–18 and 2018–19 respectively. The higher grain yield of foliar feeding may be attributed to better availability of micronutrients in foliar application than the soil application due to lack of mobility in calcareous and alkaline soils. These nutrients have specific physiological and biochemical roles of in plant growth (Putra *et al*., 2012). Since the application of Fe successfully prevented occurrence of chlorosis and the application of Zn improved the pollen formation and fertilization which improved the number of pods/plant (17.80 and 27.4%), seed yield/plant (57.45 and 46.20%) and 100-seed weight (20.79 and 16.78%) than the control in 2017–18 and 2018–19, respectively, resulting in higher yield/ha. Mousavi (2011) indicated easiness, rapid availability and reduced toxicity (accumulation and element stabilization) of foliar application of micronutrients compared to soil application. Application of Zn increased chickpea growth (Khan *et al*., 2000) and plants fertilized with Zn had a greater total dry weight (Mohan and Singh, 2014).

Significant variation in Zn and Fe content was observed between the application methods of micronutrients. Among the micronutrient application methods, foliar application of Zn and Fe at flowering and pod-initiation stage recorded significantly higher Zn (42.40 and 37.12 mg/kg) and Fe (28.06 and 29.78 mg/kg) content in grain than the control (Table 2 and Fig. 2a), showing 11.29 and 11.30% higher Zn content and 15.00 and 14.98% higher Fe content than the soil application in 2017–18 and 2018–19, respectively. Nutrients applied through foliage usually penetrate the leaf cuticle or stomata and enter the cells, facilitating easy and rapid utilization of nutrients for photosynthetic pigments, growth and yield of crop. The different transporters and chelators involved in the uptake and transport of Fe and Zn are also the same (Haydon and Cobbett, 2007), hence it enhanced the uptake of both nutrients by the plants.

Among the application methods, seed treatment recorded higher agronomic efficiency of Zn (214 kg/kg) than the other application methods (Table 2 and Fig. 2b). This was owing to the lower amount of Zn (250 g/ha) applied in the seed treatment compared to soil application (25 kg/ha) and foliar application (10 kg/ha for 2 sprays each 5 kg/ha). However, between the soil and foliar applications, foliar application of Zn and Fe showed 4–7 times higher Zn agronomic efficiency than the soil application.

Interaction of varieties and micronutrient application methods

In the present study, interaction of 'GBM 2' with foliar application of Zn and Fe resulted in significantly higher dry weight, pods/plant, seed yield/plant, 100-seed weight and yield/ha than 'JG 11' and 'GBM 2' with other methods of applications (Table 3).

Variety 'GBM 2' with Zn and Fe foliar spray exhibited significantly higher yield (2,517 and 2,005 kg/ha, respectively in 2017–18 and 2018–19) than both the varieties without Zn and Fe (2,144 and 1,725 kg/ha for 'GBM 2' and 1,952 and 1,422 kg/ha for 'JG11' in the year 2017–18 and 2018–19 respectively) and seed treatment with Zn for both the varieties (2,156 and 2,054 kg/ha for 'GBM 2' and 1,735 and 1,426 kg/ha for 'JG 11' (Table 3).

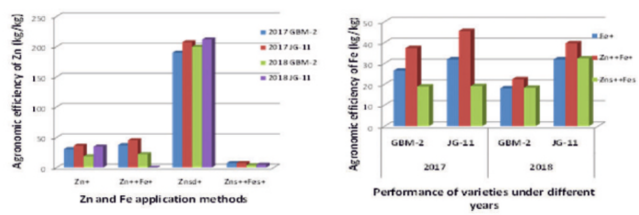

Fig. 3. Agronomic efficiency of zinc and iron in chickpea as influenced by micronutrient application methods and varieties

Table 3. Effect of interaction of micro nutrient application methods and varieties of chickpea on growth and yield parameters

Treatment	Dry weight/plant(g)				Pods/plant				Seed yield/plant (g)			
	2017–18		2018–19		2017–18		2018–19		2017–18		2018–19	
	'GBM 2'	'JG 11'	'GBM 2'	'JG 11'	'GBM 2'	'JG 11'	'GBM 2'	'JG 11'	'GBM 2'	'JG 11'	'GBM 2'	'JG 11'
Zn^-	19.2c-e	16.4f	18.1cd	16.3d	32.5cf	29.2f	24.78 e	24.78e	9.7ef	9.2f	9.68cd	8.46d
Zn^+	22.6ab	20b-e	19.2c	16.6d	36.9ab	32.6bf	34.44 bc	30.33 d	14.6ab	13.4bc	12.62ab	11.36bc
Fe^+	21.2bc	19.3c-e	19.4c	17.5cd	35.7ad	31.2 ef	36.22 ab	27.89 de	13.2bc	12.6b-d	13.09ab	12.28ab
$Zn^+ + Fe^+$	23.7a	21.2bc	21.6ab	19.2c	38.1a	34.7 ae	39.44 a	31.33cd	15.5a	14ab	13.89a	12.62ab
$Znsd^+$	20.3b-e	17.7ef	19.6bc	16.8d	34 de	30.8ef	37.67 ab	25.89 e	10.6d-f	10.1ef	11.44bc	8.9d
$Zns^+ + Fes^+$	20.7b-d	18.5d-f	22.1a	18.3cd	36.8ac	32.3df	36.11 ab	30.78 cd	12.6b-d	11.5c-e	12.69ab	10.15cd

Zn^-, RDF (control); **Zn^+**, RDF + 0.5% Zn foliar application; **Zn^- + Fe^+**, RDF + 0.1% Fe foliar application; **Zn^+ + Fe^+**, RDF + 0.5% Zn and 0.1% Fe through foliar application; **$Znsd^+$,** RDF + seed treatment 5 g Zn/kg of seeds; **Zns^+ + Fes^+,** soil application of 25 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ **RDF**, Recommended dose of fertilizer (25 : 50 : 0 N : P_2O_5 : K_2O)

- Values with similar alphabets were non-significant with each other in the above table (Tested with Duncan's Multiple Range Test)

Among the interactions, 'GBM 2' with foliar application of Zn and Fe showed significantly higher zinc content than the other methods in both the years. The Fe content was significantly superior in 'GBM 2' with foliar application of Zn and Fe and followed by application of Fe alone. However, it was on a par with 'JG 11' applied with foliar application of Fe alone and Zn and Fe (Table 4). This variety also recorded higher agronomic efficiency (Fig. 2b) under controlled condition and indicated that, it was more efficient in using native Zn and Fe than 'GBM 2', as it recorded very low yield (1,687 kg/ha) under control condition (no Zn) compared to combined foliar application of Zn and Fe (2,112 kg/ha). It also indicated that, 'JG 11' was more efficient in using native Zn and Fe than 'GBM 2'. Shivay *et al.* (2014) also concluded that 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 compared to the other genotypes and other levels of Zn.

Grain Zn content, agronomic efficiency, growth and yield of chickpea variety varied in this study. Since the variety had shown significant difference in Zn content, variety with high Zn content can be used under Zn deficiency condition to have higher Zn content in seed. Among the application methods, Zn and Fe foliar spray at the time of flower initiation and pod-development stage increased both the yield and Zn and Fe content of seed. Thus, this study provided a possibility of Zn and Fe bio-fortication through foliar application.

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Table 4. Effect of interaction of micro nutrient application methods and varieties of chickpea on yield and yield parameters

Treatment	100-seed weight (g)				Yield (kg/ha)			
	2017–18		2018–19		2017–18		2018–19	
	'GBM 2'	'JG11'	'GBM 2'	'JG11'	'GBM 2'	'JG11'	'GBM 2'	'JG11'
Zn^-	20.8bc	19.6c	19.94b-d	17.01e	2144b-d	1952d	1725b	1422b
Zn^+	24a	23.1ab	21.2ab	20.13b-d	2450ab	2315a-c	1970a	1770a
Fe^+	23ab	22.7ab	21.21ab	19.18b-e	2409ab	2271a-d	1961a	1741a
$Zn^+ + Fe^+$	24.5a	24.3a	22.84a	20.3b-d	2517a	2407ab	2005a	1818a
$Znsd^+$	21.9a-c	21bc	20.72a-c	18.2de	2296b-c	2054cd	1737b	1426b
$Zns^+ + Fes^+$	22.6ab	22a-c	19.89b-d	18.4c-e	2333a-c	2143b-d	1781a	1746a

Zn^-, RDF (control); **Zn^+**, RDF + 0.5% Zn foliar application; **$Zn^- + Fe^+$**, RDF + 0.1% Fe foliar application; **$Zn^+ + Fe^+$**, RDF + 0.5% Zn and 0.1% Fe through foliar application; **$Znsd^+$,** RDF + seed treatment 5 g Zn/kg of seeds; **$Zns^+ + Fes^+$,** soil application of 25 kg/ha $ZnSO_4$ and 10 kg/ha $FeSO_4$ **RDF**, Recommended dose of fertilizer (25 : 50 : 0 N : P_2O_5 : K_2O)

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