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Research Paper

Effect of Zn and Fe fortification through agronomic intervention on growth and yield of chickpea (*Cicer arietinum* L.)

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ABSTRACT

The present study assesses the effect of Zinc and Iron nutrition on the growth and yield of chickpea along with Zn and Fe concentrations in seed. Results of the study revealed that the cultivar GNG 2207 performed slightly better than JG 14 to seed yield (1280 kg/ha), net returns (Rs. 38992/ha) and B: C ratio (2.41). The RDF + Foliar spray of 0.5% each of $ZnSO_4$ and $FeSO_4$ at pre-flowering and pod initiation stages recorded significantly higher seed yield (1326 kg/ha), net returns (INR 41,640/ha) and B: C ratio (2.50) which was statistically at par with RDF + 0.5% $ZnSO_4$ foliar application and RDF + 0.5% $FeSO_4$ foliar application over rest of the treatments. The same results were also observed for Zn (31.28 -31.69 ppm) and Fe (60.82- 63.94 ppm) content in chickpea seed.

***Key words:** Chickpea, Fortification, Growth, Iron, Yield, Zinc*

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the leading and important *Rabi* pulse crops of India occupying a 9.46 m ha area, producing 11.58 mt with an average productivity of 1224 kg/ha during 2023-24 (Anonymous 2024). It plays an important role in the diet of the Indian population and the agricultural economy. It is high in protein, low in fat and sodium, free of cholesterol, and is an excellent source of fibre, CHO, vitamins, and minerals. Being a rich and cheap source of protein chickpeas can help people to improve the nutritional quality of their diets.

In modern agriculture, micronutrients are becoming deficient day by day due to intensive cultivation of high-yielding crop varieties, use of imbalance and high doses of fertilizers, low soil micronutrient status, and no use of organic manures for crop production, which in turn produce micronutrient deficient foods. The widespread prevalence of Fe and Zn micronutrient deficiency in human populations is due to their low intake. Deficiencies of micronutrients drastically affect the growth, metabolism, and reproductive phase of plants, animals, and human beings (Kuldeep *et al.* 2018). Micronutrient deficiencies are a significant cause of malnutrition worldwide affecting about one-third of the global population, particularly in developing countries (Ullah *et al.* 2020, Alloyway 2008) and in particular Fe and Zn deficiencies in human nutrition are widespread in developing Asian countries including India (Kuldeep *et al.* 2018). Among the pulses, chickpeas are highly sensitive to Zn and Fe deficiency in the country, which affects productivity. In developing countries, large proportions of the population consume less than the recommended dietary iron and hence face the problem of anemia. Iron deficiency limits oxygen delivery to cells, leading to fatigue, poor work performance, decreased immunity, and death (Jones *et al.* 1996). Iron is an essential micronutrient that plays a vital role in several enzymatic reactions and metabolism in plant as well as human growth. It plays an important role in several enzymic chlorophyll synthesis, nodulation, and N_2 fixation and thereby enhances the grain yield of crops. Iron deficiency causes chlorosis and necrosis in plants, restricts crop productivity and yield, and lowers the nutritional quality of grains (Phattarakul *et al.* 2012, Chen *et al.* 2017). Zinc is also an essential plant nutrient for plant growth and development and it plays an important role in the formation of chlorophyll and growth hormones. Zinc is also recognized as an essential component of several enzyme systems having vital roles in plant metabolism. Zinc helps to increase water use efficiency, nodulation, and nitrogen fixation in pulses (Roy *et al*. 2013). Zinc deficiency impairs plant growth and development by reducing enzyme activity, disturbing ribosomal stabilization, and decreasing the rate of protein synthesis. Zinc deficiency also induces flower abortion and ovule infertility leading to low seed set and substantial yield reduction. To combat micronutrient deficiency, crops must have improved nutritional qualities or be biofortified.

Bio-fortification of staple food crops with fundamental nutrients is a practical and sustainable approach, which refers to the increase in the amount and bioavailability of micronutrients in plant parts consumed by humans using nutritional management techniques and plant biotechnology (Bouis *et al.* 2011), to improve human well-being and nourishment. Bio-fortification of Fe and Zn through agronomic intervention in chickpea crops can reduce malnourishment in humans and animals (Bouis *et al.* 2011). Foliar application of micronutrients is an effective strategy for improving grain yield and enhancing micronutrient concentration in grain (Johnson *et al.* 2005, Ullah *et al.* 2020). Therefore, keeping these in view an experiment was planned to evaluate the effect of Zn and Fe nutrition on the growth and yield of chickpea as well as their concentration in the grains of chickpea.

MATERIALS AND METHODS

Experimental site and weather conditions

In the present investigation, a field experiment was conducted over two years (2021-22 and 2022-23) during the *Rabi* season at AAU-ZRS, Shillongani, Nagaon, Assam which is situated at a latitude of 26^0 N, longitude of $90^0 45^/$ E and at an altitude of 50.2 m above from the mean sea level. The soil of the experimental field was sandy clay loam having pH 5.6, organic carbon 0.82 %, available nitrogen 298.54 kg/ha, available P_2O_5 21.76 kg/ha, and K_2O 154.44 kg/ha. The climate of the experimental site was sub-tropical with hot humid summer as well as dry and cold winter. During the crop growth period, a total rainfall of 381.6 and 244.20 mm with rainy days of 36 and 24 was received during 2021-22 and 2022-23, respectively. The mean maximum and minimum temperatures ranged from 31.90 to 24.25°C and 20.95 to 11.30°C, respectively (means of two years). The weather variables during the crop season of 2021-22 and 2022-23 are presented in Figure 1.

Experimental design

The treatments comprised two chickpea cultivars and six nutrient levels which were tested in Split Plot Design with 4 replications. The main plot consisted of two chickpea cultivars viz. GNG 2207 ang JG 14 and subplot six nutrient levels *viz.* RDF (control), RDF + 0.5% $ZnSO_4$ foliar spray, RDF + 0.5% $FeSO_4$ foliar, RDF+ $ZnSO_4$ and $FeSO_4$ foliar, RDF+ Seed treatment @ 2 g $ZnSO_4$/kg of seed and RDF+ Soil application of $ZnSO_4$ @ 25 kg/ha. The plot size was 6m x 5m. The chickpea varieties were sown at 30 cm x 10 cm on November 15, 2021 and November 17, 2022, and harvested during 1st week of April during both years of experimentation. The recommended fertilizer dose (20:40:15 kg/ha as N: P_2O_5 and K_2O) was applied at the time of sowing of chickpea through urea, single super phosphate, and muriate of potash. Gap-filling and thinning operations were carried out wherever necessary to maintain the required plant population. Soil application of $ZnSO_4$ was done at the time of sowing. Foliar application of 0.5% Zn and 0.5% Fe was done through $ZnSO_4.7H_2O$ (23% Zn) and $FeSO_4.H_2O$ (20% Fe) at pre-flowering and pod initiation stage using 500 litres of water per hectare as per treatments. Weeds were controlled by one hand weeding at 30-35 DAS and 45-50 DAS. Regarding agronomic characters, five plants were randomly selected from each plot and observations were recorded for growth and yield attributes. Whereas, seed yield obtained from the net plot area was recorded and expressed in kg/ha. At harvest, plant samples were collected from each plot for chemical analysis of Zn and Fe by using di-acid ($HClO_4$ + HNO_3 in 3:10 ratio) digestion in Atomic Absorption Spectrophotometer (Prasad *et al*. 2006).

The economics was calculated based on the prevailing market price of inputs and outputs in Indian rupees. The total cost of cultivation of chickpea crops was calculated based on different operations performed and inputs used for raising the crop. The net return was calculated as:

Net return: Gross return-Cost of cultivation

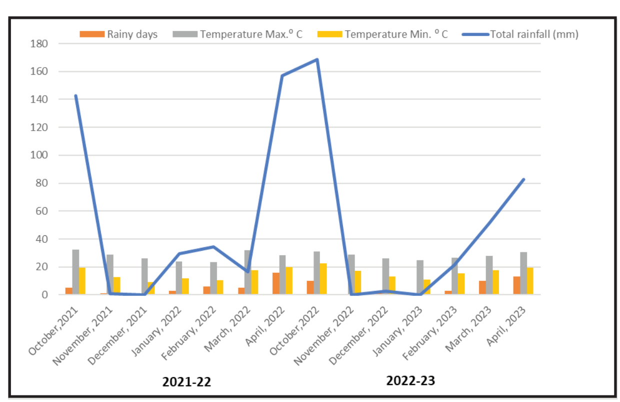

Fig. 1. Monthly weather parameters during crop season of 2021-22 and 2022-23

Statistical analysis

The data about each of the characters of the experimental crops were tabulated and finally statistically analyzed. The significance or non-significance of the variances due to treatment effects was tested by the 'F' test. Analysis of variance was performed using the online statistical program OPSTAT. Comparisons of treatment mean values were performed using the least significant difference (LSD, p=0.05).

RESULTS AND DISCUSSION

Growth attributes

Results of the present study revealed that between two chickpea varieties, GNG 2207 performed slightly better in all the growth parameters over JG 14 but failed to bring significant variation in all the growth attributes over both years except plant height during 2022-23 (Table 1). Among the nutrient levels, significantly higher plant height at 100 DAS and secondary branches per plant at 60 DAS during 2022-23, and primary branches per plant at 60 DAS in both years were found in the treatment RDF + two foliar sprays of 0.5% each of $ZnSO_4$ and $FeSO_4$ at pre-flowering and pod initiation stages which was statistically at par with RDF along with two foliar sprays of 0.5% $ZnSO_4$ and RDF along with two foliar sprays of 0.5% $FeSO_4$ as compared to rest of the treatments. Similar findings were also reported by Singh *et al.* (2015) and Banjara and Majgahe (2019).

Yield attributes

Varieties had a significant effect on pod weight per plant and seed weight per plant during 2022-23. Maximum number of pods/plant (49.58 and 53.96) and seed weight per plant (16.93 and 11.97 g) were recorded by GNG 2207 over JG 14 (Table 2). Nutrient levels had a significant effect on all the yield attributes except on pod weight per plant during 2021-22 (Table 2) and seeds per pod (Table 3). A significantly higher number of pods, pod weight, seed weight per plant, and 100 seed weight were found under the treatment RDF + two foliar sprays of 0.5% each of $ZnSO_4$ and $FeSO_4$ which was closely followed by treatment RDF + two foliar sprays of 0.5% $ZnSO_4$ and RDF + two foliar sprays of 0.5% $FeSO_4$ over rest of the treatments. The increase in yield attributes under these treatments might be attributed to the positive effect of foliar application of Fe and Zn on the growth and development of chickpea crops, as chickpea is sensitive to Fe and Zn deficiency. Similar findings were also reported by Singh *et al.* (2015) and Banjara and Majgahe (2019).

Yield

Varieties had brought significant variation in seed yield and harvest index in 2022-23 only. The chickpea variety GNG 2207 recorded significantly higher seed yield and harvest index over JG 14 (Table 4). Further, the pooled data of two years

Table 1. Effect of iron and zinc nutrition on growth parameters of chickpea

Treatments	Plant height (cm) at 100 DAS		No. of primary branches/ plants at 60 DAS		No. of secondary branches/ plant at 60 DAS	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Variety (V)						
GNG 2207	69.42	51.62	2.80	2.69	14.92	8.78
JG 14	70.33	58.03	2.78	2.57	14.37	8.07
SEm±	1.58	0.98	0.13	0.09	0.60	0.29
CD (p=0.05)	NS	4.41	NS	NS	NS	NS
Nutrient levels (N)						
RDF (control)	64.00	49.08	2.62	2.25	12.25	6.69
RDF + 0.5% ZnSO4 Foliar	72.62	57.70	3.00	2.75	15.62	9.35
RDF + 0.5% FeSO4 Foliar	71.12	56.20	2.87	2.63	14.75	7.93
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	74.87	59.20	3.38	3.28	16.87	9.76
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	66.62	51.70	2.75	2.63	13.75	8.53
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	70.00	55.08	2.12	2.25	14.62	8.30
SEm±	2.73	2.04	0.33	0.15	1.04	0.51
CD (p=0.05)	NS	6.15	0.67	0.44	NS	1.46
Interactions (VxN)	NS	NS	NS	NS	NS	NS

Table 2. Effect of iron and zinc nutrition on yield parameters of chickpea

Treatments	No. of pods/plant		Pod weight (g/plant)		Seed weight (g/plant)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Variety (V)						
GNG 2207	49.58	53.96	19.70	13.62	16.93	11.97
JG 14	46.71	49.25	19.15	12.40	16.60	11.38
SEm±	1.07	1.94	0.42	0.25	0.38	0.12
CD (p=0.05)	NS	NS	NS	1.12	NS	0.54
Nutrient levels (N)						
RDF (control)	39.62	43.13	18.02	10.60	15.32	8.51
RDF + 0.5% ZnSO4 Foliar	54.00	57.50	20.17	13.63	17.63	12.36
RDF + 0.5% FeSO4 Foliar	47.75	51.25	19.85	13.30	17.05	11.41
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	60.75	64.13	20.56	15.64	18.07	13.79
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	42.75	46.12	18.65	12.23	15.87	10.39
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	44.00	47.50	19.30	12.66	16.65	10.61
SEm±	1.85	3.36	0.72	0.43	0.65	0.22
CD (p=0.05)	5.36	9.72	NS	1.24	1.89	0.62
Interactions (VxN)	NS	NS	NS	NS	NS	NS

Table 3. Effect of iron and zinc nutrition on yield parameters of chickpea

Treatments	Seeds /pod		100 seed wt. (g)	
	2021-22	2022-23	2021-22	2022-23
Variety (V)				
GNG 2207	1.96	1.96	16.83	16.10
JG 14	1.95	1.88	23.75	22.92
SEm±	0.04	0.05	0.31	0.28
CD (p=0.05)	NS	NS	0.90	1.26
Nutrient levels (N)				
RDF (control)	1.75	1.63	19.50	18.69
RDF + 0.5% ZnSO4 Foliar	2.00	2.00	20.75	20.08
RDF + 0.5% FeSO4 Foliar	2.00	2.00	20.50	19.74
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	2.00	2.00	20.87	20.15
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	2.00	1.88	19.88	19.06
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	2.00	2.00	20.25	19.34
SEm±	0.07	0.09	0.54	0.50
CD (p=0.05)	NS	0.27	NS	NS
Interactions (VxN)	NS	NS	NS	NS

indicated that the chickpea variety GNG 2207 recorded significantly higher seed yield (1280 kg/ha) over JG 14 (Table 5). Among the different nutrient treatments, RDF + 0.5% each of $ZnSO_4$ and $FeSO_4$ foliar spray at pre-flowering and pod initiation stages had resulted in significantly higher seed yield (1326 kg/ha), stover yield and harvest index (35.82% and 36.09%) during both the years as compared to other treatments (Table 4 and Table 5). This was statistically at par with the treatments of RDF + 0.5% $ZnSO_4$ foliar spray and RDF + 0.5% $FeSO_4$ foliar application. Foliar application of $ZnSO_4$ and $FeSO_4$ at pre-flowering and pod initiation stages increased seed yield by 15.61% (Table 5) over control. The increase in seed yield of chickpeas might be attributed to higher values of growth and yield attributes associated with foliar sprays of Zn and Fe, which was due to the favourable effect of Fe and Zn on dry matter accumulation, flower formation, pollen functioning, ovule fertility and fertilization (Pathak *et al.* 2012, Choudhury *et al*. 2015).

Zn and Fe content in seed

Variety had no significant effect on Zn and Fe content in chickpea seeds. However, the chickpea variety GNG 2207 recorded a slightly higher concentration of Zn and Fe in seed as compared to JG 14. Nutrient levels showed a significant effect on Zn and Fe concentration in chickpea seeds during both years (Table 5). Application of recommended dose of NPK along with 0.5% each of ZnSO4 and $FeSO_4$ foliar spray at pre-flowering and pod initiation stages resulted in higher concentrations of Zn (31.28 ppm and 31.69 ppm in 2021-22 and 2022-23, respectively) and Fe (60.82 ppm and 62.94 ppm in 2021-22 and 2022-23, respectively) in chickpea seeds (Gupta *et al.* 2021). This was at par with the treatments of RDF + 0.5% $ZnSO_4$ foliar application and RDF + 0.5% $FeSO_4$ foliar application. However, the least Zn (23.49 ppm and 24.40 ppm in 2021-22 and 2022-23, respectively) and Fe (50.37 ppm and 51.15 ppm in 2021-22 and 2022-23, respectively) content in seed was observed in RDF *i.e.*, control. The higher Zn and Fe concentration in chickpea seeds might be attributed to the positive effect of

Table 4. Effect of iron and zinc nutrition on yield of chickpea

Treatments	Seed yield (kg/ha)		Stover yield (kg/ha)		HI (%)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Variety (V)						
GNG 2207	1263	1297	2329	2324	35.15	35.82
JG 14	1244	1253	2319	2333	34.79	34.94
SEm±	8.50	7.24	15.67	11.27	0.16	0.13
CD (p=0.05)	NS	32.55	NS	NS	NS	0.58
Nutrient levels (N)						
RDF (control)	1131	1163	2196	2205	33.99	34.54
RDF + 0.5% ZnSO4 Foliar	1292	1309	2365	2367	35.34	35.71
RDF + 0.5% FeSO4 Foliar	1278	1298	2354	2352	35.18	35.57
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	1319	1332	2364	2358	35.82	36.09
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	1241	1264	2328	2329	34.77	35.19
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	1261	1285	2336	2370	34.72	35.14
SEm±	14.72	11.96	27.15	19.42	0.27	0.31
CD (p=0.05)	42.56	36.04	78.46	58.52	0.78	0.93
Interactions (VxN)	NS	NS	NS	NS	NS	NS

Table 5. Effect of iron and zinc nutrition on yield and economics of chickpea (pooled of 2 years)

Treatments	Seed yield (kg/ha)			Gross return (INR/ha)	Net return (INR/ha)	B:C
	2021-22	2022-23	Pooled			
Variety (V)						
GNG 2207	1263	1297	1280	66687	38992	2.41
JG 14	1244	1253	1249	65579	37884	2.37
SEm±	8.50	7.24	6.64	347.55	347.27	0.013
CD (p=0.05)	NS	32.55	29.85	NS	NS	
Nutrient levels (N)						
RDF (control)	1131	1163	1147	59994	32299	2.17
RDF + 0.5% ZnSO4 Foliar	1292	1309	1301	68016	40321	2.46
RDF + 0.5% FeSO4 Foliar	1278	1298	1288	67372	39677	2.43
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	1319	1332	1326	69335	41640	2.50
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	1241	1264	1253	65505	37810	2.36
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	1261	1285	1273	66575	38880	2.40
SEm±	14.72	11.96	11.99	627.14	627.17	0.023
CD (p=0.05)	42.56	36.04	34.80	1820.08	1820.17	0.066
Interactions (VxN)	NS	NS	NS	NS	NS	NS

foliar fertilization of Zn + Fe in plants, as foliar spray of micronutrients regulates their supply to the crop through mineralization and prevents them from leaching and other losses due to directly applied to the leaves (Kumar *et al.* 2020). A similar result was also noticed by Hidoto *et al.* (2017), Pal *et al.* (2019) and Gupta *et al.* (2021).

Economics

In respect of economics also, variety GNG 2207 performed better compared to JG 14 (Table 5). Among the nutrient treatments, the treatment RDF + 0.5% each of $ZnSO_4$ and $FeSO_4$ foliar spray at pre-flowering and pod development stages recorded significantly higher gross return, net return, and B:C ratio and it was closely followed by RDF + 0.5% $ZnSO_4$ foliar application. This might be attributed to the higher productivity of the crop associated with the treatment compared to others. Similar findings were also reported by *Gupta et al.* (2021) and Majeed *et al.* (2020).

Table 6. Effect of iron and zinc nutrition on Fe and Zn content in seed of chickpea

Treatments	Zn content in seed (ppm)		Fe content in seed (ppm)	
	2021-22	2022-23	2021-22	2022-23
Variety (V)				
GNG 2207	28.26	28.95	56.63	61.14
JG 14	27.59	28.20	55.52	59.30
SEm±	0.44	0.32	0.88	0.70
CD (p=0.05)	NS	NS	NS	NS
Nutrient levels (N)				
RDF (control)	23.49	24.40	50.37	51.15
RDF + 0.5% ZnSO4 Foliar	29.76	30.85	55.91	62.27
RDF + 0.5% FeSO4 Foliar	26.37	26.87	59.04	62.23
RDF + 0.5% ZnSO4 + 0.5% $FeSO_4$ Foliar	31.28	31.69	60.82	63.94
RDF + Seed treatment @ 2 g ZnSO4/kg of seed	26.53	28.40	54.79	60.36
RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	30.13	29.34	55.54	61.33
SEm±	0.76	0.54	1.53	1.02
CD (p=0.05)	2.21	1.63	4.44	3.07
Interactions (VxN)	NS	NS	NS	NS

CONCLUSION

Based on the above results, it can be concluded that the application of the recommended dose of fertilizers (RDF) along with 0.5% each of Zn and Fe foliar fertilization has a positive effect on Zn and Fe content of chickpea seeds along with higher seed yield and economics. It is a viable agronomic intervention for getting higher productivity, profitability, and nutritional security. Thus, it can help in eliminating the micronutrient malnutrition of Zn & Fe in human beings.

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