International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(5): 284-287
www.biochemjournal.com
Received: 09-02-2025
Accepted: 12-03-2025

Rekha Kharra
Department of Agronomy, College of Agriculture, AU, Jodhpur, Rajasthan, India

UN Shukla
Department of Agronomy, College of Agriculture, AU, Jodhpur, Rajasthan, India

Corresponding Author:
UN Shukla
Department of Agronomy, College of Agriculture, AU, Jodhpur, Rajasthan, India

Agronomic biofortification of zinc and iron on iron fortification in chickpea (*Cicer arietinum* L.) varieties under arid western plains zone of Rajasthan

Rekha Kharra and UN Shukla

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i5d.4327

Abstract

Background: According to the World Health Organization, zinc and iron deficiencies are ranked fifth and sixth among the ten most important variables in developing countries, respectively, and eleventh among the twenty most significant factors worldwide. Iron (Fe) and zinc (Zn) deficiencies in human diet are common in developing Asian nations, such as India. Therefore, the easiest and most effective method of adding zinc and iron to seeds is agronomic biofortification, which may help reduce malnutrition in developing countries like India.

Methods: In the Arid Western Plains Zone of Rajasthan, a field experiment was carried out to investigate the agronomic biofortification of zinc and iron in chickpea (*Cicer arietinum* L.) types. Cultivation of two types, RSG-974 and GNG-1581, together with seven fortification methods contained different zinc and iron dosages provided under FRBD, and the study was conducted throughout the 2019-20 rabi season at the Instructional Farm, College of Agriculture, Jodhpur, Rajasthan.

Result: The findings showed that applying $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) resulted in a considerably greater seed, stover, and biomass yield. Additionally, applying $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) to chickpea variety GNG-1581 resulted in higher iron levels and their uptakes.

Keywords: Zinc, yield, iron, chickpea, and bio fortification

Introduction

According to the 4th advance estimates, chickpeas (*Cicer arietinum* L.) account for 10.17 million hectares in India, producing 11.35 million tonnes with an average productivity of 1116 kg ha^{-1} in 2019-20. India leads the world in chickpea output and area, followed by Australia, Pakistan, and Turkey. Chickpeas are a vital crop for vegetarians as a key source of protein; after dry beans and peas, they are the third most important pulse crop globally (Kaur *et al*., 2020) [4]. One of the eight essential trace elements required by plants for development and reproduction is zinc. Deoxyribonucleic acid (DNA), ribonucleic acid (RNA), and other proteins' transcription, regulation, and signal transduction all depend on zinc-enriched finger proteins. Plant its absence results in inadequate production of phytohormones, such as auxins, gibberellins, and cytokinins, which inhibits crop growth and development (Hassan *et al*., 2020) [2]. Zinc helps pulse crops fix inert nitrogen in the root nodule and is involved in plant root nodulation. Additionally, it participates in signal transduction when the plant is under stress system. Similarly, the world's cereal-based cropping systems are more likely to have soil zinc deficiencies, which have an impact on subsequent pulse crops (Shukla and Mishra, 2020) [14]. However, iron (Fe) is also crucial for the synthesis of chlorophyll and serves as a structural element of heme, hematin, and leghaemoglobin, which are involved in the nitrogen fixation in pulses that are catalyzed by an "nitrogenase" is an enzyme.

Furthermore, according to Larson *et al*. (2018) [6], iron is the most important micronutrient for plant growth, particularly for chickpeas cultivated in salty and alkaline soils. Despite iron's widespread existence in the crust of the planet, its low solubility reduces its availability and, ultimately, its poor absorption by crops. Similar to this, iron deficiency in salty and alkaline soils causes chlorosis in the leaves, which lowers the chickpea's photosynthetic potential and prevents it from completing the development of pods or grains; eventually, pods may remain empty (Vadlamudi *et al*., 2020; Shukla and Mishra, 2018) [15, 13].

Materials and Methods

During the 2019-20 rabi season, an experiment was conducted at the Instructional Farm, College of Agriculture, Jodhpur, Rajasthan. The distance between here and the Jodhpur railway station is roughly 10 km. Geographically, it lies between latitudes 26°15°N and 26°45°N. and at a height of 231 meters above mean sea level, from latitude 73°00°E to longitude 73°29°East The study included two types, GNG-1581 and RSG-974, and seven fortification treatments, which included different zinc (Zn) and iron (Fe) dosages and application methods: control (F0), $ZnSO_4$ @ 25 kg ha^{-1} (SA) (F1), $FeSO_4$ @ 25 kg ha^{-1} (SA) (F2), $ZnSO_4$ @ In total, fourteen treatment combinations were created using a factorial randomized block design (FRBD) with three replications, resulting in forty-two plots: 25 kg ha^{-1} (SA) + 0.5% $ZnSO_4$ (FA) (F3), $ZnSO_4$ @ 25 kg ha^{-1} (SA) + 0.5% $FeSO_4$ (FA) (F4), $FeSO_4$ @ 25 kg ha^{-1} (SA) + 0.5% $ZnSO_4$ (FA) (F5), and $FeSO_4$ @ 25 kg ha^{-1} (SA) + 0.5% $FeSO_4$ (FA) (F6). The experimental plot's soil had a sandy-loam texture, a pH of 8.2, a slightly alkaline soil response, a nonsaline conductivity (EC 0.12 d/Sm), a low level of organic carbon (0.14%), and 176 kg of accessible nitrogen ha^{-1}), while there is a high level of accessible potassium (329 kg ha^{-1}) and a medium level of phosphorus (22.0 kg ha^{-1}). According to the soil's micronutrient analysis, the experimental soil had low levels of available zinc (0.48 mg kg-1) and accessible iron (3.21 mg kg-1). Chickpeas were sown with the appropriate fertilizer dosage (20 N and 40 kg P2O5 ha^{-1}). However, ferrous sulphate (Fe 19.5%) and zinc sulphate heptahydrate (Zn 21%) were utilized as sources of iron and zinc used as agronomic fortification in accordance with the treatments. Every cultural procedure was carried out in accordance with the Chickpea suggestion package. However, in accordance with all standard procedures provided by Isaac and Kerber (1971) [3], zinc and iron were examined by wet digestion in a di-acid mixture (HNO_3 + $HClO_4$ in a 3:1 ratio) in flower and stockpile samples utilizing Atomic The most sensitive wavelength for iron (248.3 nm) and zinc (213.7 nm) is used by the absorption spectrophotometer.

Results and Discussion

Effect of varieties on yield

Table 1 presents and summarizes the impact of varieties on yield. Data analysis revealed that variety GNG-1581 produced noticeably more biomass (4402 kg ha^{-1}), stover yield (2863 kg ha^{-1}), and seed yield (1539 kg ha^{-1}) than variety RSG-974, which recorded 1326 kg ha^{-1} of seeds, 2466 kg ha^{-1} of stover, and 3792 kg ha^{-1} of biomass were produced. The formation of additional growth and yield attributes, or the individual potential of a variety that synthesizes more reproductive components, may be the cause of the increased chickpea yield. This would likely improve the production of chickpea yield characters, which would ultimately yield more. The outcomes are is consistent with the findings of Nandan *et al*. (2018) [7] and Parmar and Poonia (2020) [9].

Varieties' effects on iron absorption and content

Table 2 presents and summarizes the impact of cultivars on iron content and absorption. Iron concentration in seed (56.95 mg kg-1) and stover (313.19 mg kg-1) was found to be significantly greater, and their uptake by seed (88.21 g ha^{-1}) and stover (907.28 g ha^{-1}) was also shown to be significantly higher than total Compared to RSG-974, uptake (995.49 g ha^{-1}) was noted under variety GNG-1581. The genetic composition of each plant variety may have contributed to the variations in iron content and their uptake in seed and stover. Similar patterns were also noted by Prasad and Shivay (2018) [11] and Nandan *et al*. (2018) [7].

Impact of iron and zinc agronomic bio fortification on yield

Table 1's data showed that agronomic biofortification of zinc and iron had a substantial impact on chickpea yields. $ZnSO_4$ @ 25 kg ha^{-1} (SA) + 0.5% $FeSO_4$ (FA) and $ZnSO_4$ @ 25 kg ha^{-1} (SA) + 0.5% $ZnSO_4$ (FA) were found to be considerably observed greater biomass yield (4876 and 4521 kg ha^{-1}), stover yield (3049 and 2886 kg ha^{-1}), and seed yield (1827 and 1635 kg ha^{-1}), respectively, and demonstrated their notable superiority over the remaining treatments, with the exception of stover yield, where both treatments were statistically equal. Shivay *et al*. (2014) [12] and Parmar and Poonia (2020) [9] also endorsed these theories. The fact that the simultaneous application of zinc and iron boosted the availability of major and minor nutrients to the plant may be the cause of improvements in chickpea variety yield. May have promoted early root development and cell division, which would have increased the absorption of additional nutrients from deeper soil layers and, in turn, the supply of the main nutrients. Because micronutrient supplies (Zn and Fe) promote cell differentiation at the reproductive stage, this could lead to the production of increased yield qualities.

Efficacy of iron and zinc agronomic bio fortification on iron absorption and content

As compared to the other treatments, the application of $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) resulted in a considerably greater zinc content in the stover (390.83 mg kg-1) and seed (69.17 mg kg-1) due to the higher yield that $FeSO_4$ produced Iron uptake by chickpea seed (93.91 and 92.16 g ha^{-1}) and stover (1040.43 and 904.51 g ha^{-1}) as well as their total uptake (996.67 and 1,134.34 g ha^{-1}), respectively, was significantly improved by @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) and $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA); both treatments, however were comparable in terms of iron uptakes (Table 2) These findings were consistent with those of Pal (2018) [8] and Nandan *et al*. (2018) [7].

Varieties' interactions and agronomic bio fortification of iron and zinc (C × F)

Table 3 shows the interactions between varieties and agronomic biofortification of iron and zinc. Among treatment combinations, RSG-974 showed a considerably higher iron concentration (74.34 mg/kg) in seed when $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) was applied and stover (401.55 mg/kg) of variety GNG-1581 treated with $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA) had a higher iron concentration and was significantly superior to the other treatments, with the exception of the treatment that received $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA), where both treatments were found to be statistically equivalent. Iron uptake in seed was substantially greater in chickpea variety GNG-1581 when $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) was applied, while iron uptake in seed was significantly higher in variety GNG-1581 when $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA) was applied Stover iron uptakes (1,230.45 g/ha) and its total uptake (1,328.02 g/ha) were comparable to the treatment with $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA), which recorded stover iron uptakes (1,133.81 g/ha) and its total uptake (1,225.47). The findings also align with those of Kayan *et al*. (2015), Nandan *et al*. (2018) [7], and Pal (2018) [8]. This could be because iron and zinc have a positive association, which activates different enzymes to create signal transduction through transcription factors, allowing for the acquisition of additional iron and zinc from roots to shoots (Pal, 2018 and Pingoliya *et al*., 2015) [8, 10].

Table 1: Effect of agronomic biofortification of Zn and Fe on seed yield, stover yield and biomass production of chickpea varieties

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Biomass production (kg/ha)
Varieties			
C_1: GNG-1581	1,539	2,863	4,402
C_2: RSG-974	1,326	2,466	3,792
SEm±	26.47	43	51.39
CD (P= 0.05)	76.95	124	149.38
Zinc and Iron levels			
F_0: Control	1,108	2,226	3,334
F_1: $ZnSO_4$ @ 25 kg/ha (SA)	1,311	2,554	3,865
F_2: $FeSO_4$ @ 25 kg/ha (SA)	1,248	2,489	3,737
F_3: $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA)	1,635	2,886	4,521
F_4: $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA)	1,827	3,049	4,876
F_5: $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA)	1,535	2,787	4,322
F_6: $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA)	1,363	2,661	4,024
SEm±	49.52	80	96.14
CD (P= 0.05)	143.96	232	279.47
Interaction (C × F)			
SEm±	70.04	112.75	135.96
CD (P= 0.05)	203.60	NS	NS

*(SA = Soil application & FA = Foliar application)

Table 2: Effect of agronomic biofortification of Zn and Fe on Fe contents and uptakes in seed and stover of chickpea varieties

Treatment	Fe content (mg/kg)		Fe uptake (g/ha)		Total Fe uptake (g/ha)
	Seed	Stover	Seed	Stover	
Varieties					
C_1: GNG-1581	56.95	313.19	88.21	907.28	995.49
C_2: RSG-974	54.99	267.28	73.61	658.52	732.13
SEm±	0.38	8.80	1.65	27.48	27.23
CD (P= 0.05)	1.09	25.58	4.80	79.87	79.17
Zinc and Iron levels					
F_0: Control	42.03	211.76	46.43	473.05	519.48
F_1: $ZnSO_4$ @ 25 kg/ha (SA)	51.28	227.09	67.40	586.57	653.97
F_2: $FeSO_4$ @ 25 kg/ha (SA)	56.76	299.36	70.84	741.32	812.16
F_3: $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA)	53.67	272.41	87.97	809.64	897.61
F_4: $ZnSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA)	58.75	305.13	107.65	924.80	1,032.45
F_5: $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $ZnSO_4$ (FA)	60.14	325.06	92.16	904.51	996.67
F_6: $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA)	69.17	390.83	93.91	1,040.43	1,134.34
SEm±	0.70	16.46	3.09	51.40	50.95
CD (P= 0.05)	2.05	47.86	8.97	149.42	148.11
Interaction (C × F)					
SEm±	1.00	23.28	4.36	72.69	72.05
CD (P= 0.05)	2.89	67.68	12.69	211.31	209.46

*(SA = Soil application & FA = Foliar application)

Table 3: Interaction effects of varieties and agronomic biofortification of zinc and iron on iron contents in seed and stover of chickpea

C × F	Varieties					
	Seed			Stover		
	C_1	C_2	Mean	C_1	C_2	Mean
F_0	50.61	33.45	42.03	205.62	217.89	211.76
F_1	52.26	50.31	51.28	293.78	160.40	227.09
F_2	56.66	56.85	56.76	288.55	310.16	299.36
F_3	56.20	51.14	53.67	401.55	143.28	272.41
F_4	59.56	57.94	58.75	291.17	319.09	305.13
F_5	59.36	60.93	60.14	314.15	335.98	325.06
F_6	64.01	74.34	69.17	397.48	384.18	390.83
Mean	56.95	54.99		313.19	267.28	
SEm±		1.00			23.28	
CD (P=0.05)		2.89			67.68	

Table 4: Interaction effects of varieties and agronomic biofortification of zinc and iron on iron uptakes (g/ha) by seed and stover of chickpea

C × F	Varieties								
	Seed			Stover			Total uptake		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
F_0	55.46	37.40	46.43	490.06	456.04	473.05	545.52	493.44	519.48
F_1	77.83	56.97	67.40	790.68	382.47	586.57	868.51	439.44	653.97
F_2	74.37	67.32	70.84	760.64	722.00	741.32	835.01	789.32	812.16
F_3	97.57	78.38	87.97	1,230.45	388.82	809.64	1,328.02	467.20	897.61
F_4	115.64	99.66	107.65	965.41	884.18	924.80	1,081.05	983.84	1,032.45
F_5	104.95	79.37	92.16	979.93	829.09	904.51	1,084.88	908.46	996.67
F_6	91.67	96.14	93.91	1,133.81	947.06	1,040.43	1,225.47	1,043.21	1,134.34
Mean	88.21	73.61		907.28	658.52		995.49	732.13	
SEm±		4.36			72.69			72.05	
CD (P=0.05)		12.69			211.31			209.46	

Conclusion

According to the experimental findings, cultivating the chickpea variety GNG-1581 under $FeSO_4$ @ 25 kg/ha (SA) + 0.5% $FeSO_4$ (FA) demonstrated superior agronomic bio fortification treatment, which notably and interactively increased seed yield (1,539) kg ha^{-1}) and also enhanced the seed with a greater iron content in contrast to variety RSG-974.

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