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Effect of Sulphur and Zinc Levels on Growth And Yield Of Chickpea (*Cicer Arietinum* L.) Under Semi-Arid Eastern Zone of Rajasthan

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Abstract
During the Rabi season of 2024–2025, a field experiment was carried out at Agronomy Research Farm, Nirwan University Jaipur, to assess the impact of zinc and sulfur levels on chickpea (Cicer arietinum L.) growth and yield. Ten treatments, including RDF (Control) and combinations of sulfur (10, 15, and 20 kg/ha) and zinc levels (0, 2.5, and 5.0 kg/ha), were used in the randomized blocked design experiment, which was repeated three times. The findings showed that using zinc and sulfur together greatly enhanced chickpea yield, yield characteristics, and growth factors. Treatment T10 (RDF + 20 kg Sulphur ha-1 + 5.0 kg Zinc ha-1) produced the highest plant height, dry matter per plant, nodules per plant, and their dry weight per plant. Similarly, the combined application of 20 kg sulfur + 5.0 kg zinc/ha together with RDF produced the highest seed yield (2181 kg/ha), haulm yield (3210 kg/ha), and biological output (5391 kg/ha), which was statistically comparable to T7, T8, and T9 and significantly greater than the remainder of the treatment. Treatment T10 (RDF + 20 kg Sulfur ha-1 + 5.0 kg Zinc ha-1) also reported the highest gross returns, net returns, and B-C ratio.
Keywords: *Chickpea, Growth parameters, Root nodules, Seed Yield, Sulphur, Zinc*

Introduction

Pulses play very vital role in vegetarian diets to provide nutritional security as a major source of protein in developing countries. Pulses are also good source of essential amino acids, dietary fibres, vitamins and minerals. Among pulses, chickpea (*Cicer arietinum* L.) is most prominent and important pulse crop in India, which cultivated during *Rabi* season and commonly known as Gram and Bengal gram. Chickpea belong to the family *fabaceae* and sub-family Papilionaceae. It contains 17-21 % digestible dietary protein, 61.5 % carbohydrate and 4.5 % protein (Diapari *et al*., 2014). Chickpea also rich in iron, calcium, vitamin-B niacin, and vitamin-C. It also maintains soil fertility and soil health through the symbiotic nitrogen fixation from atmosphere with rhizobium.

In India, chickpea is one of the most important pulse crop which grown during *rabi* season and among pulses, it secure ranks first in both area and production. During 2024-25, chickpea covered an area of 9.12 m ha producing 11.11 m t at an average productivity of 1218 kg/ha (MoA & FW, 2025). Among different stated and union territories, Rajasthan secure second position in area after Maharashtra and third position in production after Maharashtra and Madhya Pradesh, respectively. Rajasthan contributed 18.14 % (1.66 m ha) in acreage and 18.98 % (2.66 m t) in production with an average productivity of 1215 kg/ha (MoA & FW, 2025). Chickpea primarily cultivated in arid and semi-arid districts of Rajasthan on marginal and low productive land with less and no use of fertilizers. Chickpea crop also grown under residual moisture conditions on well drained soils due to its drought tolerant nature.

After the green revolution, intensive agriculture and imbalanced fertilizer use in crop production cause multi-nutrient deficiencies in Indian soils particularly macronutrients and micronutrients (NAAS, 2018). In India, more the 40 % cultivated area are sulphur deficient and widespread in light texture soil. As sulphur is the fourth most important essential nutrient after nitrogen, phosphorus and potassium. It is essential for protein, vitamins, enzymes and chlorophyll formation in plants. Sulphur required in large amount in protein synthesis and as constituent of sulphur amino acids *viz*., Cystine, Cysteine and methionine (Thompson *et al*., 1983). It is also involved in the respiration, photosynthesis and symbiotic nitrogen fixation as constituent of ferrodoxin containing nitrogenase which promotes nodulation in legumes crop. Under the sulphur deficient conditions, chickpea with poor nodulation may be retarded nitrogen fixation. Continuous indiscriminative use high analytic fertilizers and intensive cropping system resulting sulphur deficiency which becoming major constraints for increasing pulses productivity in arid and semi-arid areas.

On the same note, micro nutrients deficiency becomes major constraint for lower productivity and nutritional value of pulses specially in zinc deficient soil. Zinc is the one of the micro nutrients that needed for normal plant growth and reproduction. It required in small but critical concentrations play vital role in photosynthesis, membrane function, protein synthesis, phytohormone synthesis (*e.g.* auxine), sugar formation, seedling vigor and defensive mechanism against abiotic and abiotic factors (Alloway, 2008). Zinc also essential for auxin metabolism like tryptamine and IAA synthesis. It is associated with plant water uptake and its retention in the plants. Zinc is a constituent of three enzymes *viz*., Carbonic anhydrase, Alcoholic dehydrogenase and Superoxide dismutase which involved in carbohydrate metabolism. The balanced and adequate amount of secondary and micronutrient along with primary nutrient may lead to the productivity of the chickpea in marginal and sub-marginal areas.

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So, it is essential to evaluate the optimum level of sulphur and zinc for higher productivity and profitability in semi-arid region of Rajasthan.

Materials and Methods

During the Rabi season of 2024–2025, the field experiment was carried out at the Agronomy research farm at Nirwan University in Jaipur, Rajasthan. The location is roughly 430 meters above mean sea level, at latitude 26°55′ N and longitude 75°47′ E. With a pH of 7.9, organic carbon of 0.31%, available nitrogen of 180.58 kg/ha, low available phosphorus of 18.75 kg/ha, medium potassium of 291.20 kg/ha, low available sulfur of 7.8 kg/ha, and low DTPA extractable zinc of 0.47 ppm, the soil at the experimental site was sandy loam in texture and slightly alkaline in reaction.

The experiment was laid out in randomized block design consisting with three replication of ten treatments *viz*., T1 - Control (RDF - NPK 20:40:20 kg/ha), T2 - RDF + 10 kg/ha, T3 - RDF + 10 kg/ha + 2.5 kg Zn/ha, T4 - RDF + 10 kg/ha + 5 kg Zn/ha, T5 - RDF + 15 kg/ha, T6 - RDF + 15 kg/ha + 2.5 kg Zn/ha, T7 - RDF + 15 kg/ha + 5 kg Zn/ha, T8 - RDF + 20 kg/ha, T9 - RDF + 20 kg/ha + 2.5 kg Zn/ha, T10 - RDF + 20 kg/ha + 5 kg Zn/ha. The recommended doses of fertilizers (RDF - NPK 20:40:20 kg/ha) were applied as basal and at the time of sowing. The gradual levels of sulphur and zinc were applied plot wise as per treatment through bentonite sulphur (90% SO_4^{-2}) and zinc oxide (78% Zn), respectively and mixed in soil after layout before sowing. Chickpea variety GNG-2144 was sown at a seed rate of 80 kg/ha and at spacing 30 x 10 cm^2. Two hours before to seeding, rhizobium culture was added to chickpea seeds. Five randomly tagged plants in a net plot were used to record the growth parameter and yield attributes. Plant height was measured at 30 and 60 DAS, as well as at harvest time, and the mean value was given in centimetres (cm). Three randomly chosen plants had their dry matter accumulation measured in grams per plant at 30, 60, and harvest. Samples were collected from the second-to-last rows and sun-dried before being stored in an oven to achieve a consistent weight. At 45 DAS, the number of nodules and their dry weight (g) were noted.

From every plot has five plants are randomly selected from border rows for counting of nodules. Immediately after counting, the nodules from each sampled plant were collected and dried to determine their dry weight. The nodules were first air-dried and then oven dried at 70°C for 24 hours to a constant weight. At the time of harvest, border row harvested initially individual plot wise. Subsequently, net plot was harvested and tagged properly. The haulm yield was determined by deducting the seed yield from the biological yield of the corresponding plot and represented in kg/ha, while the total produce from the net plot was weighed as biological yield after cleaning and seed yield was recorded. Each treatment's cost of cultivation (₹/ha) was calculated by taking into account the current market prices for materials, labour, land, cultivation fees, and other costs. The current market prices of straw and chickpea grain were used to determine the gross return. For each treatment, the B:C ratio was computed by dividing net returns by the entire cost of cultivation, which was deducted from the corresponding gross returns to determine net returns. To arrive at reliable conclusions, growth, yield, and economic data were tallied and statistically analyzed using the conventional "analysis of variance" (Gomez and Gomez, 1984). Based on the null hypothesis, the "F" test was used to examine treatment differences. When the "F" test was significant, critical differences were calculated at the 5% level of significance.

Results and Discussion

Effect of sulphur and zinc levels on growth parameter of chickpea

The data displayed in the table indicates that varying levels of zinc and sulfur have a substantial impact on chickpea development and output.

The treatments T9 (RDF + 20 kg Sulphur/ha + 5.0 kg Zinc/ha), T8 (RDF + 20 kg Sulphur/ha), T7 (RDF + 15 kg Sulphur/ha + 5.0 kg Zinc/ha), and T6 (RDF + 15 kg Sulphur/ha) were statistically comparable with the highest plant heights of 26.3, 44.0, and 59.0 cm at 30 DAS, 60 DAS, and harvest.

However, under control-RDF (T1), the lowest plant height was recorded at 30, 60, 90 DAS, and harvest (21.4, 34.8, 46.7, and 48.1 cm, respectively). With regard to dry matter per plant, a similar outcome was also noted. When 20 kg of sulfur and 5.0 kg of zinc were applied per hectare together with RDF at 30, 60 DAS, and harvest, the maximum amount of dry matter per plant was measured. Applying zinc and sulfur together greatly enhanced the number of nodules per plant and their dry weight. With the exception of T8 and T9, the application of 20 kg sulfur + 5.0 kg zinc/ha together with RDF at 45 DAS resulted in the highest number of nodules per plant.

When 20 kg of sulfur and 5.0 kg of zinc were applied together with RDF, the dry weight of nodules per plant was substantially higher than in the other treatments. A balanced and sufficient supply of nutrients, particularly zinc and sulfur, in addition to fundamental nutrients may be the cause of the notable rise in chickpea development indices. Better cell division, cell elongation, meristematic tissue development, cell multiplication, synthesis of essential amino acids, carbohydrate metabolism, auxin synthesis, protein metabolism, and hormone synthesis may be the cause of the marked increase in growth parameters caused by the availability of zinc and sulfur (Thompson et al., 1986; Alloway, 2008). These results are consistent with those of Patel et al. (2014), Tripathi et al. (2019), and Bisen et al. (2023).

Effect of sulphur and zinc levels on yield attributes and yield of chickpea

The rising amounts of zinc and sulfur had a substantial impact on the yield characteristics and chickpea yield. The application of 20 kg sulfur/ha and 5

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kg zinc/ha together with RDF resulted in a significantly greater number of pods (36.5 plant-1) and seeds (1.94 pod-1), which remained statistically consistent with the T9, T8, and T7. With the exception of T9 and T8, the maximum test weight (195.2 g) was observed with T10, which was noticeably greater than the other treatments.

Maximum seed production (2121 kg/ha) and biological yield (5391 kg/ha) were obtained when 20 kg sulfur and 5 kg zinc/ha were applied in conjunction with RDF. These results were much greater than those of the other treatments, with the exception of T9. However, T10 produced the highest haulm yield (3210 kg/ha), which was significantly greater than the other treatments and remained statistically comparable to T9, T8, and T7. The substantial increase in chickpea production and yield characteristics may be caused by adequate sulfur and zinc availability, which improves the metabolism of carbohydrates and increases the activity of photosynthesis-related enzymes, resulting in the transfer of photosynthates from sink to source. Ram and Katiyar (2013), Gautam et al. (2022), and Bisen et al. (2023) have found similar findings.

Effect of sulphur and zinc levels on economics

An analysis of the data revealed that as sulfur and zinc levels rose, chickpea cultivation's net returns, gross returns, and B:C ratio all considerably increased.

The maximum net returns, gross returns and B: C ratio (₹1,40,367/ha, ₹1,04,167/ha and 2.88, respectively) was obtained under T_{10} (RDF + 20 kg sulphur + 5.0 kg zinc/ha, respectively), followed closely by T_9 (₹1,37,543/ha, ₹1,02,043/ha, 2.87, respectively), T8 (₹1,34,786/ha, ₹99,986/ha, 2.87, respectively), and T_7 (₹1,31,994/ha, ₹95,994/ha, 2.67, respectively). Conversely, the lowest net returns, gross return and B: C ratio (₹1,06,886/ha, ₹73,386/ha, 2.19, respectively) was recorded under T_1 (control - RDF).

Conclusion

Results from a one-year field experiment showed that applying zinc and sulfur together greatly increased the growth and output of chickpeas. Applying 20 kg S + 5.0 kg Zn/ha in conjunction with RDF (NPK 20:40:20 kg/ha) enhanced biological yield (5391 kg ha-1), haulm (3210 kg ha-1), and seed (2181 kg ha-1) with net returns of ₹1,40,367/ha and a B-C ratio of 2.88. Therefore, in Rajasthan's semi-arid climate, applying 20 kg S + 5.0 kg Zn/ha in addition to RDF (NPK 20:40:20 kg/ha) showed to be the most effective way to improve growth, productivity, and profitability in chickpea production.

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Table 1. Effect of sulphur and zinc levels on growth parameters of chickpea

Treatments Name	Plant Height (cm)			Dry matter/plant (g)			Root nodules/plant	Dry weight of root nodules (g)
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest	45 DAS	45 DAS
T_1 - Control - RDF (NPK 20:40:20 kg ha^{-1})	21.4	34.8	48.1	1.82	4.76	11.24	18.4	0.105
T_2 - RDF + 10 kg Sulphur ha^{-1}	23.5	37.9	52.0	2.04	5.32	12.18	22.7	0.124
T_3 - RDF + 10 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	24.0	39.1	53.8	2.10	5.47	12.65	24.1	0.133
T_4 - RDF + 10 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	24.5	40.0	54.2	2.18	5.62	13.02	25.4	0.139
T_5 - RDF + 15 kg Sulphur ha^{-1}	25.2	41.3	56.0	2.21	5.78	13.48	26.2	0.144
T_6 - RDF + 15 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	25.5	42.5	57.1	2.26	5.89	13.75	27.5	0.151
T_7 - RDF + 15 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	25.8	43.0	57.8	2.30	6.02	14.12	28.4	0.157
T_8 - RDF + 20 kg Sulphur ha^{-1}	26.0	43.4	58.3	2.34	6.10	14.35	29.1	0.163
T_9 - RDF + 20 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	26.2	43.8	58.6	2.38	6.18	14.59	30.0	0.167
T10 - RDF + 20 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	26.3	44.0	59.0	2.42	6.25	14.88	30.8	0.173
SEm ±	0.52	0.67	0.78	0.07	0.12	0.20	0.65	0.0034
CD (P=0.05)	1.53	1.98	2.30	0.21	0.36	0.61	1.89	0.0098

Table 2. Effect of sulphur and zinc levels on yield and economics of chickpea

Treatments Name	Yield Attributes			Yield (kg/ha)			Economics (₹/ha)		B-C ratio
	Number of Pods/Plant	Number of Seeds/Pod	Test Weight (g)	Seed	Haulm	Biological	Gross returns	Net Returns	

T_1 - Control - RDF (NPK 20:40:20 kg ha^{-1})	24.3	1.48	171.2	1623	2875	4498	106886	73386	2.19
T_2 - RDF + 10 kg Sulphur ha^{-1}	28.6	1.61	177.4	1740	2948	4688	113920	79720	2.33
T_3 - RDF + 10 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	30.4	1.68	180.6	1806	2981	4787	117847	82947	2.38
T_4 - RDF + 10 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	31.2	1.72	183.1	1883	3015	4898	122406	86806	2.44
T_5 - RDF + 15 kg Sulphur ha^{-1}	32.8	1.78	185.8	1930	3052	4982	125270	90770	2.63
T_6 - RDF + 15 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	33.5	1.81	188.0	1987	3096	5083	128739	93439	2.65
T_7 - RDF + 15 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	34.2	1.86	190.3	2042	3120	5162	131994	95994	2.67
T_8 - RDF + 20 kg Sulphur ha^{-1}	35.0	1.88	192.1	2088	3154	5242	134786	99986	2.87
T_9 - RDF + 20 kg Sulphur ha^{-1} + 2.5 kg Zinc ha^{-1}	35.8	1.91	193.5	2134	3181	5315	137543	102043	2.87
T10 - RDF + 20 kg Sulphur ha^{-1} + 5.0 kg Zinc ha^{-1}	36.5	1.94	195.2	2181	3210	5391	140367	104167	2.88
SEm ±	0.85	0.04	1.25	26.7	34.9	45.2	-	-	-
CD (P=0.05)	2.46	0.12	3.64	78.2	102.1	132.6	-	-	-