Original Research Article

"Influence of Sulphur and Zinc on growth and yield of Chickpea (*Cicer arietinum* L.)"

Abstract

A field experiment was conducted "Influence of Sulphur and Zinc on growth and yield of chickpea (*Cicer arietinum*)" during *Rabi* season of 2021-22 with 9 treatments (viz. S at 20, 30, 40 kg/ha respectively and Zn at 10, 15, 20 kg/ha respectively) at the CRF (Crop Research Farm), Department of Agronomy, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh. The treatments comprised T1 – Sulphur 20 kg/ha + Zinc 10 kg/ha, T2 – Sulphur 20 kg/ha + Zinc 15 kg/ha, T3 – Sulphur 20 kg/ha + Zinc 20 kg/ha, T4 – Sulphur 30 kg/ha + Zinc 10 kg/ha, T5 – Sulphur 30 kg/ha + Zinc 15 kg/ha, T6 – Sulphur 30 kg/ha + Zinc 20 kg/ha, T7 – Sulphur 40 kg/ha + Zinc 10 kg/ha, T8 – Sulphur 40 kg/ha + Zinc 15 kg/ha, T9 – Sulphur 40 kg/ha + Zinc 20 kg/ha. Application of Sulphur 40 kg/ha + Zinc 20 kg/ha recorded highest plant height (44.11 cm), plant dry weight (8.05 g/plant), number of nodules/plant (42.40), number of pods/plant (31.53), number of seeds/pod (1.73), seed index (237.67 g), seed yield (1819.00 kg/ha) and stover yield (3253.67 kg/ha), highest gross returns (13,0068.00 INR/ha), net return (92527.62 INR/ha) and benefit: cost ratio (2.40)

Key words: Economics, Growth parameter, Chickpea, Sulphur, Zinc, Yield parameter.

Introduction

Chickpea (*Cicer arietinum*) is the second important pulse crops that belongs to the legume family. The crop is mainly produced for human consumption, animal feed and as a rotational crop with cereal. Pulse production in India is about 25.72 million ~~tones~~tonnes with area of under cultivation around 288.3 lakh hectares and pulse production in Uttar Pradesh is 2.62 million ~~tones~~tonnes with area of under cultivation around 0.81 lakh hectares **(GOI-2021)**. In India chickpea had a lion share of 49.3% in total pulse production **(ICRISAT-2021)**, signifying its importance in Indian agriculture production. India produces alone more than 60% of world chickpea production.

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Chickpea is one of the major *rabi* pulse crop which as high digestible dietary protein (17-21 percent). Chickpea is also rich in calcium iron, niacin, vitamin C and B. Its leaves contain maleic acid which is very useful for stomach ailments and blood purification. chickpea is a good source of carbohydrates, minerals, and trace elements. On average dry chickpea kernels contains 56% fat, 47% starch, 23% protein, 6% soluble sugar, 6% crude fiber and 3% ash **(Goa, 2014).**

Sulphur attributed to increase the number of nodules/plants resulting from improved root growth (Lange *et al.,* 1994). Sulphur plays an important role in enhancing the productivity and quality of chickpea. The importance of S in balance plant nutrition is realized with an increasing S deficiency in several areas due to intensive cropping and focus on high yielding varieties. In Gujarat, 17% of soils are deficient in available ~~sulphur~~Sulphur **(Golakiya ~~and Shobhana~~et al. 2006~~0~~).** Optimization of macro and micro nutrient application will enhance the productivity of chickpea. Sulphur is considered as the four major nutrient after N, P and K. It is basically required for synthesis of proteins, especially S-containing amino acid i.e., methionine, cystine and cysteine and as a constituent of vitamins (thiamine and biotin) and other biologically active compounds like lipoic acid, acetyl coenzyme-A, ferredoxin and glutathione.

Chickpea is mostly grown in rainfed areas and marginal soils with low available zinc (Zn); Zn deficiency induces flower abortion and ovule infertility, leading to low seed set and substantial yield reductions. About 49% of Indian soils are deficient in zinc and response to Zn application has been reported for a number of crops including chickpea. Zinc plays an important role in formation of chlorophyll and growth hormones. Zinc is also an essential plant nutrient for plant growth and development. Zn is recognized as essential component of several enzyme systems having vital roles in the plant metabolism, e.g. carbonic anhydrase for reversible hydration of CO_2 to form HCO_3^- for transport and utilization of CO_2 in photosynthesis. It is also responsible for resisting pH changes in cytoplasm. Zn is involved in auxin metabolism like, tryptophan synthesis, tryptamine metabolism. Thus, the present investigation was undertaken with the objective to determine the effect of different levels of Sulphur as well as Zinc on growth and yield of Chickpea.

MATERIALS AND METHODS

The experiment was carried out during Rabi season of 2021 at the CRF (Crop Research Farm) , Department of Agronomy, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj, Uttar Pradesh. The crop Research Farm is situated at 25.75 0 N latitude, 87.19 E longitude and at an altitude of 98m above mean sea level. This area is situated on the right side of the river Yamuna and by the opposite side of Prayagraj City.

All the facilities required for crop cultivation were available. The experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.9), low in organic carbon (0.112%), available N (278.93 Kg/ha), available P (10.8 Kg/ha) and available K (206.4 Kg/ha). The crop was sown on 16th November 2021 using Pusa-362 variety. The experiment was laid out in Randomized Block Design comprised of 3 replications and total 9 treatments viz. T1 – Sulphur 20 kg/ha + Zinc 10 kg/ha, T2 – Sulphur 20 kg/ha + Zinc 15 kg/ha, T3 – Sulphur 20 kg/ha + Zinc 20 kg/ha, T4 – Sulphur 30 kg/ha + Zinc 10 kg/ha, T5 – Sulphur 30 kg/ha + Zinc 15 kg/ha, T6 – Sulphur 30 kg/ha + Zinc 20 kg/ha, T7 – Sulphur 40 kg/ha + Zinc 10 kg/ha, T8 – Sulphur 40 kg/ha + Zinc 15 kg/ha, T9 – Sulphur 40 kg/ha + Zinc 20 kg/ha. All nutrients were applied into the soil in the form of Urea, Single super phosphate (SSP) and Muriate of potash (MOP). Entire dose of P and K was applied basal for respective plots, half dose of N (as urea) was applied as basal, one-fourth at 30 days after sowing and remaining one-fourth at the time of flowering. Sulphur levels are (20,30,40 kg/ha) and Zinc levels are(10,15,20kg/ha) was applied as soil application along with NPK fertilizers before sowing. The growth parameters were recorded at periodical intervals of 20,40,60,80,100 DAS and at harvest stage from the randomly selected five plants in each treatment.

Statistically analysis was done for all the parameters in one way Anova and mean compared at 5% probability level of significant results.

Result and Discussion

Effect of Sulphur and zinc on growth parameters of chickpea are given in table 1.

Plant height

At 100 DAS, significantly higher plant height (44.11cm) was recorded in the treatment-9 (Sulphur 40kg/ha +zinc 20kg/ha). However, the treatment-8 (sulphur 40 kg/ha + Zinc 15 kg/ha) (43.75 cm) were found to be statistically at par with treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). The increase in plant height of plants under zinc treatment may be due to its effect in the metabolism of growing plants, which may effectively explain the observed response of zinc application. Favourable responses of zinc application on plant height are similar in findings of **Khalil and Prakash (2014) and Masih *et al.,* (2020).**

Number of nodules/plant

At 100 DAS, significantly higher number of nodules/plant (20.96) was recorded in treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). However the treatment -8 (Sulphur 40 kg/ha + Zinc 15 kg/ha) (20.50) was found to be statistically at par with the treatment -9 (sulphur 40 kg/ha + Zinc 20 kg/ha). The increase in number of nodules/plant is due to the increase in the availability of sulphur which helps in better nodule formation, increase in nitrogenase enzyme, chlorophyll content etc. and thereby influencing growth components of the crop which is also similar in the findings of **Yadav *et al.,* (2017), Kumar *et al*., (2000) and Singh *et al.,* (2020).**

Dry matter accumulation

At 100 DAS, significantly higher plant dry weight (8.05 g/plant)) was recorded in treatment-9 (sulphur40 kg/ha + Zinc 20 kg/ha). However, the treatment-8 (sulphur 40 kg/ha + Zinc 15 kg/ha) (7.97 g/plant) were found to be statistically at par with treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). Zinc plays an activator of several enzymes in plants and it is directly involved in the biosynthesis of growth substances such as Auxin thereby producing more plant cells and enhanced dry matter **(Aboyeji *et al.,* 2019).**

YIELD PARAMETERS

Effect of Sulphur and zinc on yield parameters of chickpea are given in table 2.

Pods/plant

At harvest significantly highest number of pods/plant (31.53) was recorded with the treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha) over all the treatments. whereas the treatment-1 (sulphur 20 kg/ha + Zinc 10 kg/ha) (27.30) was found to be lowest. The increase in seeds per pod might be due to more availability of zinc nutrition to plant at all the growth stages in the findings of **Deb Roy *et al.,* (2013).**

Seeds/pod

At harvest significantly maximum number of seeds/pod (1.73) was recorded with the treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha) over all the treatments. whereas the treatment-1 (sulphur20 kg/ha + Zinc 10 kg/ha) (1.58) was found to be lowest. There will be a significant increase in number of seeds/pod with application of Sulphur along with the application of recommended dose of fertilizer. This might be due to activation of enzymes by application of Sulphur **(Mitra *et al.,* 2006) and Raj et al., (2018).**

Seed index (g)

At harvest significantly higher seed index (237.67 g) was recorded in treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha) over all the treatments. However, the treatment-8 (sulphur 40 kg/ha + Zinc 15 kg/ha) (229.33) were found to be statistically at par with treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). The increase in seed index might be due to the application of Sulphur along with the application of recommended dose of fertilizer. This might be due to the application of Sulphur which helps in chlorophyll formation, photosynthetic process, activation of enzymes and grain formation **Singh *et al.,* (2004).**

Seed yield (kg/ha)

At harvest significantly maximum seed index (1819 kg/ha) was recorded in treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha) over all the treatments. However, the treatment-8 (sulphur 40 kg/ha + Zinc 15 kg/ha) (1793.67 kg/ha) were found to be statistically at par with treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). Maximum seed yield might be due to pivotal role of sulphur in regulating the metabolic and enzymatic processes including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation which reflected in increased yield. The other reasons may be due to the important role of sulphur in energy transformation, activation of enzymes and also in carbohydrate metabolism. The third reason may be due to optimum availability of available sulphur which consequently resulted in well filled pods resulting in increased seed yield. These results are in conformity with those of **Ghosh and Sarkar (2000) and Patel *et al*.,(2006).**

Stover yield (kg/ha)

At harvest significantly maximum seed index (3253.67 kg/ha) was recorded in treatment-9 of (sulphur 40 kg/ha + Zinc 20 kg/ha) over all the treatments. However, the treatment-8 (sulphur 40 kg/ha + Zinc 15 kg/ha) (3122.67 kg/ha) were found to be statistically at par with treatment-9 (sulphur 40 kg/ha + Zinc 20 kg/ha). Maximum stover yield obtained may be due to increased metabolic process in plants due to sulphur application through ZnSO4 and SSP. These results are in findings with **Khorgamy and Farina, (2009) and Teja *et al.,* (2020).**

Harvest index (%)

Significantly maximum harvest index (41.58%) was recorded in treatment-5 (sulphur 30 kg/ha + Zinc 15 kg/ha) over all the treatments. However, the treatment-1 (sulphur 20 kg/ha + Zinc 10 kg/ha), treatment-2 (sulphur 20 kg/ha + Zinc 15 kg/ha),treatment- 3 (sulphur 20 kg/ha + Zinc 20 kg/ha) treatment-4 (sulphur 30 kg/ha + Zinc 10 kg/ha) and treatment-7 (sulphur 40kg/ha + zinc 10kg/ha) (40.06%, 40.28%, 40.72%, 39.81% and 40.12% respectively) were found to be statistically at par with treatment-5 (sulphur 30 kg/ha + Zinc 15 kg/ha).Highest harvest index was observed due to cell activities, enhanced cell multiplication and enlargement and luxuriant growth and yield attributes of the crops probably due to more absorption and utilization of available nutrients leading to overall improvement of crop growth reflected to source-sink relationship, which in turn enhanced the yield attributes that ultimately more yield. **Kokani *et al*., (2015)**

Economics

Gross returns (INR/ha)

Gross returns (130068.00 INR/ha) were found to be highest in treatment-9 (sulphur 40kg/ha + zinc 20kg/ha) and the minimum gross returns (102200.00 INR/ha) was found in treatment-1 (sulphur 20kg/ha + zinc 10kg/ha) as compared to other treatments.

Net returns (INR/ha)

Net returns (92,527.62 INR/ha) were found to be highest in treatment-9 (sulphur 40kg/ha + zinc 20kg/ha) and the minimum net returns (68509.62 INR/ha) was found to be I treatment-1 (sulphur 20kg/ha + zinc 10kg/ha) as compared to other treatments.

Benefit Cost Ratio (B:C)

Benefit Cost Ratio (2.40) was found to be highest in treatment-9 (sulphur 40kg/ha + zinc 20kg/ha) and the minimum Benefit Cost Ratio (1.97) was found in treatment-1 (sulphur20kg/ha + zinc 10kg/ha). B:C ratio increased significantly due to successive increasing levels of sulphur along with zinc. **Singh *et al*.,(*et al.* (2013)**

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It is necessary to discuss these results, with emphasis on the causes of the matter. Therefore I recommend citing the scientific manuscripts.

The most limiting nutrients for chickpea production are phosphorus (P), calcium (Ca), sulfur (S), molybdenum (Mo), boron (B) and zinc (Zn), our results being a interesting contribution particularly with sulfur and zinc, and pointing out the edaphic relationships with the productivity of crops in tropical territories (Olivares, 2016; 2022).

It is interesting to note that the chickpea is a crop that requires less water than corn, so it has potential as a plant that can be grown in this region, since its nutritional value is also valued in the diet [Bertorelli y Olivares, 2020; Olivares et al. 2018]. Despite the foregoing, and particularly under humid conditions in the study area, the species by itself cannot guarantee high yields, so it is necessary to accompany its planting with adequate in situ rainwater harvesting practices, which have implicit techniques that, in addition to making better use of rain (because it increases the amount of water available for plants) [Olivares, 2018; Olivares et al. 2017; Olivares et al. 2017], followed by practices that help conserve the soil, with the consequent benefits [Olivares et al. 2018a; 2018b].

Certain environmental characteristics of the region under study determine that there are high temperatures during the day and cooler (lower) temperatures at night, which, for a species such as the chickpea, is extremely important for the production of dry matter, since there are temperatures within the optimum during the day for photosynthesis, and on the other hand, low temperatures at night reduce respiratory rates and consequently the production of dry matter is more efficient [Olivares y Hernandez, 2019; Casana y Olivares, 2020; Olivares et al. 2021], this added to The edaphic factors studied in this research can have a direct effect on yield, as reported by studies focused on the influence of soil conditions on productivity in environments such as the one in our study [Olivares et al. 2020; Olivares et al.2022].

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Conclusion

Based on experimental findings it was concluded that Treatment combination of Sulphur 40 kg/ha and Zinc 20 kg/ha recorded maximum plant height, plant dry weight, number of nodules/plant, number of pods/plant, number of seeds/pod, seed index, seed yield, stover yield, gross return, highest net return and benefit: cost ratio which may be more preferable for farmers since it is economically more profitable and hence, can be recommended to the farmers.

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Table 1 Influence of Sulphur and Zinc on growth attributes of Chickpea.

S.No.	Treatments	At Harvest			At 80-100 DAS	
		Plant height(cm)	Nodules/plant	Plant dry weight (g/plant)	Crop growth rate ($g/m^2/day$)	Relative growth rate (g/g/day)
1	Sulphur 20 kg/ha + Zinc 10 kg/ha	40.61	17.16	7.21	2.05	0.017
2	Sulphur 20 kg/ha + Zinc 15 kg/ha	41.21	17.87	7.34	1.9	0.016
3	Sulphur 20 kg/ha + Zinc 20 kg/ha	41.97	19.11	7.6	2.26	0.013
4	Sulphur 30 kg/ha + Zinc 10 kg/ha	41.79	18.52	7.55	1.97	0.011
5	Sulphur 30 kg/ha + Zinc 15 kg/ha	42.48	19.4	7.66	1.99	0.016
6	Sulphur 30 kg/ha + Zinc 20 kg/ha	43.53	20.17	7.82	1.93	0.016
7	Sulphur 40 kg/ha + Zinc 10 kg/ha	42.96	19.79	7.7	1.93	0.014
8	Sulphur 40 kg/ha + Zinc 15 kg/ha	43.75	20.5	7.97	1.98	0.019
9	Sulphur 40 kg/ha + Zinc 20 kg/ha	44.11	20.96	8.05	1.92	0.023
	F test	S	S	S	S	NS
	S. EM (±)	0.15	0.15	0.04	0.06	0.00
	CD (P=0.05)	0.45	0.44	0.13	0.19	---

Table 2 Influence of Sulphur and Zinc on yield attributes and yield of Chickpea.

Treatments	At harvest					
	Pods/plant	Seed/pod	Seed index (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
1. Sulphur 20 kg/ha + Zinc 10 kg/ha	27.30	1.25	191.00	1460.00	2185.67	40.06
2. Sulphur 20 kg/ha + Zinc 15 kg/ha	27.57	1.33	194.33	1486.67	2203.33	40.28
3. Sulphur 20 kg/ha + Zinc 20 kg/ha	28.03	1.42	202.00	1589.33	2315.00	40.72
4. Sulphur 30 kg/ha + Zinc 10 kg/ha	27.67	1.37	197.33	1503.33	2273.67	39.81
5. Sulphur 30 kg/ha + Zinc 15 kg/ha	28.87	1.45	207.33	1654.00	2333.33	41.58
6. Sulphur 30 kg/ha + Zinc 20 kg/ha	29.96	1.54	216.33	1771.67	2833.33	38.54
7. Sulphur 40 kg/ha + Zinc 10 kg/ha	29.70	1.49	211.67	1683.33	2526.33	40.12
8. Sulphur 40 kg/ha + Zinc 15 kg/ha	30.17	1.58	229.33	1793.67	3122.67	36.49
9. Sulphur 40 kg/ha + Zinc 20 kg/ha	31.53	1.73	237.67	1819.00	3253.67	35.86
F test	S	S	S	S	S	S
S. EM (±)	0.24	0.04	3.04	20.24	98.28	0.98
CD (P = 0.05)	0.72	0.11	9.12	60.67	294.64	2.93

Table 3.Influence of Sulphur and Zinc on Economics of production of Chickpea

Treatments	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	(B:C) ratio
1. Sulphur 20 kg/ha + Zinc 10 kg/ha	33,690.38	1,02,200.00	68,509.62	2.03
2. Sulphur 20 kg/ha + Zinc 15 kg/ha	34,990.38	1,04,020.00	69,020.62	1.97
3. Sulphur 20 kg/ha + Zinc 20 kg/ha	36,290.38	1,11,253.10	74,962.72	2.06
4. Sulphur 30 kg/ha + Zinc 10 kg/ha	34,764.38	1,05,233.10	70,468.72	2.02
5. Sulphur 30 kg/ha + Zinc 15 kg/ha	36,064.38	1,15,780.00	79,715.62	2.21
6. Sulphur 30 kg/ha + Zinc 20 kg/ha	37,364.38	1,24,016.90	86,652.52	2.31
7. Sulphur 40 kg/ha + Zinc 10 kg/ha	35,840.38	1,17,833.10	81,992.72	2.28
8. Sulphur 40 kg/ha + Zinc 15 kg/ha	37,140.38	1,25,556.90	88,416.52	2.38
9. Sulphur 40 kg/ha + Zinc 20 kg/ha	38,440.38	1,30,068.00	92,527.62	2.40