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Interaction effect of sulphur and zinc on growth and yield of chickpea (*Cicer arietinum* L.) under rainfed

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Abstract
A field experiment was conducted during rabi 2019-20 at the Rajaula Research Farm, Faculty of Agricultural Science, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna, (M.P.). Interaction effect of Sulphur and Zinc on growth and yield of mustard (*Cicer arietinum* L.) under rainfed condition. On a study sandy loam soil having low status of available nitrogen, low status of available phosphorus and medium status of available potassium. The treatment consisted of three levels of Sulphur (0, 15 and 25 kg S ha^{-1}) and three levels of zinc (0, 10 and 15 kg Zn ha^{-1}) applied from gypsum and zinc sulphate respectively. On the basis of the results emanated from present investigation, it could be concluded that growth parameter i.e., plant height, primary and secondary branches, length of root, no. of root nodules and yield attributes i.e., no. pod plant^{-1}, no. of seed pod^{-1}, test weight (1000 grain) and productivity parameter i.e., grain yield (q ha^{-1}) were increased with increase in level of Sulphur and zinc individually as well as in various combination. Chickpea variety JG-14 was grown with the recommended agronomic practices. The synergistic effect of Sulphur and Zinc was reported on plant height, no. of pod plant^{-1}, no. of seed pod^{-1} and seed yield.

Keywords: Growth, interaction, mustard, sulphur, zinc and yield

Introduction
Chickpea (*Cicer arietinum* L.) is the largest produced food legume in South Asia and the third largest production food legume globally, after common beans and pea it belongs to the family Fabaceae. More than 50 countries are reported to grow chickpea; 22 cultivate more than 20,000 ha, and 19 cultivate 10,000 to 20,000 ha. Major chickpea-production countries are: India (65% of annual production), Pakistan (10%), Turkey (7%), Iran (3%), Myanmar (2%), Mexico (1.5%) and Australia (1.5%) (FAO, 2008). Australia (1.5%) (FAO, 2008). In India chickpea grown area 9995.75-thousand-hectare, production 11911.18 thousand tonnes and productivity 1192 kg/hectare in rabi 2020-21. In Madhya Pradesh chickpea grown area 2160.00-thousand-hectare, production 3214.08 thousand tonnes and productivity 1488 kg/hectare in rabi 2020-21(Anonymous, 2020-21). Chickpea is an important source of protein for millions of people in the developing countries, particularly in South Asia, who are largely vegetarian either by choice or because of economic reasons. In addition to having high protein content (20-22%), chickpea is rich in fiber, minerals (phosphorus, calcium, magnesium, iron and zinc) and B-carotene. Its lipid fraction is high in unsaturated fatty acids. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80% of its nitrogen requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha -1 from air. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility. Because of its deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile.

Sulphur, in chickpea, mainly influences the protein content as it helps in conversion of nitrogen into protein in pulse crops. Sulphur also improves the S containing amino acid in crop where it directly influencing the nutritional qualities. It is also necessary for chlorophyll formation and enhance the biosynthesis of oil and metabolism of carbohydrates, proteins and fats and thus now-a-days Sulphur is being considered as the fourth major nutrient element after NPK. An adequate supply of mineral nutrients to legumes enhances nitrogen fixation Ganeshamurthy *et al*., (2000) [1].

Zinc plays a role in the detoxification of superoxide radicals, membrane integrity as well as synthesis of protein and phyto hormones like IAA.

Chickpea is generally considered as a sensitive crop to zinc deficiency. Zinc deficiency affects plant-water relationships, including stomatal closure and decrease transpiration in plants. Zinc deficient plants appear stunted and have fewer branches. The size reduction of leaflets and delayed crop maturity are common. The younger leaves become pale green first then a reddish-brown discoloration appears on margins on margins of leaflets and on the lower part of the stem. In the later stage the upper portion of the leaflet turns bronzed and necrotic (Kumar and Sharma, 2013) [4].

Materials and Methods

Field experiments were conducted during the rabi 2019-20 at the experimental Farm of Rajola the faculty of agriculture science at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna, (M.P.). The farm is situated at 24^0 31' N latitude and 81^0 15' E longitude. The soil of the experimental site was sandy loam and slightly alkaline in reaction (P^H 7.7), organic carbon 0.33%, low in available nitrogen 202.36 kg N ha^{-1}, low available phosphorus 16.12 kg ha^{-1}, and medium in available potassium 246.22 kg ha^{-1}, respectively. The Sulphur status was 15.88 kg S ha^{-1} and the available Zinc was 0.54 mg kg ha^{-1} soil. The treatments consisted of three Sulphur levels *viz.* ($S_{0\text{ – control}}$, S_1 – 15 kg ha^{-1} and S_2 – 25 kg ha^{-1}; three zinc levels *viz.* Zn_0 – control, Zn_1 – 10 and Zn_2 – 20 kg Zn ha^{-1}). The experiments were laid out in a randomized block design and three replications. The grated levels of Sulphur and Zinc were applied through gypsum and Zinc Sulphate and mixed in soil after layout before sowing. Healthy seeds of chickpea cv. JG – 14 were sown @ 80 kg ha^{-1}. The sowing of chickpea seed was done using the hand plough at 6-8 cm depth in mid-October. Five re-presentive plant of chickpea from each treatment were selected randomly at 30, 60 90 DAS and at maturity for recording biometric observation. The experiment data were statistically analyzed by applying "Analysis of variance" technique for randomized block design. The standard error of mean (SEM-+) and critical difference level were worked out for each parameter.

Results

Growth attributes parameters

Plant height (cm plant^{-1})

Plant height data were recorded at 30 DAS, 45 DAS and finally at the harvest stage. The results are presented in Table 1. It showed that plant height varied from 11.85 to 12.57 cm. These values were observed in control and S_1 Zn_2, very closely followed by S_1 Zn_2 and both were at par. The general mean height was 12.57 cm. The main effects of Sulphur showed that all the levels were significantly superior to control. Increasing levels of Sulphur increased the plant height linearly and significantly with maximum value of 13.56 cm at Zn_2. In case of the main effects of S_0, S_1 and were significantly better than control differ significantly with each other. Thus, S_2 and Zn_2 appeared to be best treatments in respect of their main effects Sulphur x Zinc interaction was also not significant, at 30 DAS. At 45 DAS, the plant height varied from 20.82 to 25.10 cm, with a mean of 23.28 cm. Increase in plant height due to different treatments was significant the lowest and the highest values were given by control and S_1 Zn_2 and this combination was the best one. Regarding the main effects of Sulphur, all the treatments were significantly superior over control. Significant increase in S_0 was recorded over S_0 but S_1 and S_2 were at par. At the harvest the plant height varied from 41.12 to 55.12 cm and the minimum and maximum values were observed in control S_0 Zn_0 and S_1 Zn_2. Each increase in Sulphur levels gave significant increase in plant height. In case of main effects of Zn_0, Zn_1 was significantly superior over control but Zn_0 did not differ significantly from Zn_2. The interaction Sulphur x Zinc was not significant.

Table 1: Interaction of Sulphur and Zinc levels on Plant height (cm plant^{-1}) at different growth intervals

Level of S (kg ha^{-1})	Levels of Zn (kg ha^{-1})			Mean
	0	10	15	
	30 DAS			
0	11.05	11.92	12.59	11.85
15	11.88	12.46	13.56	12.63
25	12.10	12.56	13.04	12.57
Mean	11.66	12.32	13.06	
	S	Zn	S×Zn	
S.E. (m)+	0.10	0.10	0.17	
CD(p=0.05)	0.30	0.30	N/S	
45 DAS				
0	20.82	22.35	24.53	22.57
15	21.30	23.16	26.13	23.53
25	21.66	23.07	25.10	23.28
Mean	21.26	22.86	23.25	
	S	Zn	S× Zn	
S.E. (m)+	0.18	0.18	0.31	
CD(p=0.05)	0.54	0.54	N/A	
At harvest stage				
0	41.12	46.47	52.47	46.68
15	43.07	48.82	57.95	49.95
25	44.66	50.73	55.12	50.17
Mean	42.95	48.67	55.18	
	S	Zn	S× Zn	
S.E. (m)+	0.21	0.21	0.37	
CD(p=0.05)	0.64	0.64	1.12	

Root length plant^{-1}

Observations on root length were recorded at 45 DAS and the data are presented in Table 2. It was revealed that no definite trends in the variations of root length were visible due to different treatments and the results were not significant. Root length varied from 7.80 to 12.43 cm. significant response, however, were observed due to Sulphur and Zinc levels to root length at 45 DAS. Where in it was revealed that root length with a mean of 9.66 and 10.61 cm. The lowest and the highest values were recorded in control and S_1 Zn_2. Regarding the main effects of Sulphur all the treatments were significantly superior to control. S_1 was significantly superior to S_2 and were also significantly different from S_0. In case of Zn_1 and Zn_2 were significantly superior over control and Zn_2 was also significantly superior to Zn_2. Sulphur x Zinc interactions was not significant.

Number of primary branches plant^{-1}

The branches were counted at one stage i.e., 30 DAS of crop growth. Magnitude of increase in branch number through different stages of crop growth the data are given in Table 2. However, the treatment effects were significant. The main effects of Sulphur spray showed that at 30 DAS S_1 was non significantly higher than control and S_2 gave significantly higher value than that of S_1. But there was significant difference between S_0 and S_1. Zn_2 in case of Zinc was significantly superior to control and at par with that of Zn_2.

Thus, S_1 and Zn_2 were better than other levels. The interaction of Sulphur x Zinc was also non-significant. Number of branches plant^{-1} varied from 3.06 to 3.73 with a mean of 3.52.

Number of secondary branches plant^{-1}

The data on sub-branches or secondary branches grow at the later half period of crop growth and, therefore, the data were collected at 30 DAS and harvest stages only. The results are projected in Table 2, which showed that number of sub-branches plant^{-1} varied from 9.40 to 10.58 with a general mean of 10.28. The increasing responses of Sulphur and Zinc were not significant. Except S_1 and S_2 all the levels were significantly different from each other. S_1 and S_2 were at par. The highest number was observed in Zn_2 which was significantly superior to Zn_0 and Zn_1. The interaction was also non-significant in Sulphur x Zinc.

Table 2: Interaction of phosphorus and Sulphur levels on growth attributing at different growth intervals.

Level of S (kg ha^{-1})	Levels of Zn (kg ha^{-1})			Mean
	0	10	20	
	Root length plant^{-1}			
0	7.80	9.53	9.66	9.66
15	8.50	10.13	10.68	10.68
25	8.93	10.46	10.61	10.61
Mean	8.41	10.04	12.51	
	S	Zn	S×Zn	
S.E. (m)+	0.17	0.17	0.29	
CD (p=0.05)	0.52	0.52	N/A	
	No. of primary branches plnat^{-1}			
0	3.06	3.40	3.70	3.38
15	3.33	3.43	3.93	3.56
25	3.33	3.50	3.73	3.52
Mean	3.24	3.44	3.78	
	S	Zn	S× Zn	
S.E. (m)+	0.03	0.03	0.06	
CD (p=0.05)	0.11	0.11	N/A	
	No. of secondary branches plnat^{-1}			
0	9.40	9.99	10.46	9.92
15	9.23	10.13	10.28	10.20
25	9.93	10.12	10.59	10.28
Mean	9.68	10.12	10.59	
	S	Zn	S× Zn	
S.E. (m)+	0.02	0.02	0.03	
CD (p=0.05)	0.06	0.06	0.10	

Yield attributes parameters

Number of pods plant^{-1}

At the time of harvesting the data were recorded on number of pods plant^{-1} and the results are given in Table 3. Large variations were observed in pod number under the influence of different treatment. The number ranged from 31.42 to 47.63, and these values were given by control and S_1Zn_2. S_1 was significantly superior to S_2 and S_0 was significantly higher than control but the difference between S_1 and S_2 was significant. Increasing levels of Zinc gave a linear and significant increase in pod number and Zn_2 gave the highest number.

Number of seed/pods/plant

At the time of harvesting the data were recorded on number of seed pods plant^{-1} and the results are given in Table 3. Low variations were observed in pod number under the influence of different treatment. The number ranged from 25.33 to 33.66 and these values were given by control and S_1Zn_2. S_1 were significantly superior to S_0 and S_2 was significantly lower than control but the difference between S_1 and S_2 were not significant. Increasing levels of Zinc gave a linear significant increase in pod number and S_O gave the lowest number.

Table 3: Interaction of Sulphur and Zinc levels on yield attributing at different growth intervals.

Level of S (kg ha^{-1})	Levels of Zn (kg ha^{-1})			Mean
	0	10	20	
	No. of pod Plant^{-1}			
0	31.42	37.59	45.47	38.16
15	33.77	40.69	50.26	41.57
25	36.07	44.14	47.63	42.61
Mean	33.75	40.81	47.78	
	S	Zn	S×Zn	
S.E. (m)+	0.29	0.29	0.51	
CD(p=0.05)	0.89	0.89	1.55	
	No. of Seed pod^{-1}			
0	25.33	28.66	32.33	28.77
15	26.66	29.66	34.66	30.33
25	27.00	30.33	33.66	30.33
Mean	26.33	29.55	33.55	
	S	Zn	S× Zn	
S.E. (m)+	0.30	0.30	0.52	
CD(p=0.05)	0.91	0.91	N/S	
	Test Weight (1000 grain) in gram			
0	157.06	159.83	155.71	157.54
15	156.26	152.36	158.63	155.75
25	161.66	156.06	155.06	157.60
Mean	158.33	156.08	156.47	
	S	Zn	S× Zn	
S.E. (m)+	2.19	2.19	3.97	
CD(p=0.05)	N/S	N/S	N/S	

Grain test weight

Sufficient variation under the influence of fertilizers was observed in test weight (weight of 100 grain in gram) as shown in Table 3. It was evident that test weight varied from 157.06 to 155.06 g 100 grain. These values were given by control and S_1Zn_2 respectively and this treatment the best. Considering the main effects of Sulphur and Zinc it was revealed that all the levels were significantly better than control. There existed a significant difference between S_1 and S_0 which gave the mean values of 158.63 and 157.06 respectively was significant difference between S_1 and S_2, father the value was marginally decreased at 50 as compared to S_1. Regarding the main effect of Zinc, Zn_0 was significantly superior to control but it was significantly different from Zn_2. Thus, the combined dose of S_1 and Zn_2 was the best dose in this respect. The positive interaction Sulphur x Zinc was not significant.

Grain yield

The grain yield (q/ ha^{-1}) of chickpea is given in Table 4. The yield varied significantly due to fertilizer treatments. It ranged from 9.16 to 15.90 qha^{-1} and the highest in S_1 Zn_2. But this value were statistically non-significant from those of S_1 Zn_0 and 15 S_1 15 kg/ha Zn_2 (17.89 qha^{-1}). The main effects of Sulphur showed that there was a linear and significant increase in grain yield over control. The magnitude of increase due to S_2 and S_1 was respectively over control. However at S_2 the magnitude of increase significant decreases in yield Thus 15 kg/ha S_1 gave the highest grain yield. The main effect of Zinc showed that both Zn_1 and Zn_2 were significantly superior over control. Zn_2 was significantly better than control but Zn_0 and Zn_1 did not differ significantly, although 15 kg/ha Zn_2 gave numerically higher yield (17.89 q ha^{-1}) than 25 kg/ha S_2 (15.90 q ha^{-1}). Thus it was clear that 15 kg/ha Zn_2 was a better dose than Zn_1. It was further indicated that yield tended to increase at (15 kg/ha) S_1 (15 kg/ha) Zn_2 level to a significant extent as compared to that of S_2 and Zn_2 level. It was, therefore, evident that maximum grain yield was obtained by (15 kg/ha) S_1 (15 kg/ha) Zn_2 (S_1 Zn_2) combination. The effect of interaction of Sulphur x Zinc was also significant.

Table 4: Interaction of Sulphur and Zinc levels on seed yield and stover yield at different growth intervals.

Level of S (kg ha^{-1})	Levels of Zn (kg ha^{-1})			Mean
	0	10	20	
	Seed yield (q ha^{-1})			
0	9.16	13.13	15.83	12.90
15	10.63	13.72	17.89	14.08
25	11.46	13.88	15.90	13.75
Mean	10.41	13.57	16.54	
	S	Zn	S×Zn	
S.E. (m)+	0.26	0.26	0.46	
CD(p=0.05)	0.80	0.80	1.40	

Discussion

In the present study the yield varied from 9.16 to15.90 qha^{-1} under rain fed conditions and under rain fed conditions it may be considered satisfactory since the native status of soil in respect of Sulphur and Zinc was low. Moreover, the crop was further stained of moisture. High responses of applied nutrients on grain yield of chickpea recorded in this study are as expected. The grain yield tended to decrease to a significant extent at S_1 and Zn_2. This might be ascribed to the antagonistic effect of Sulphur and Zinc which was expressed at the highest levels of these nutrients. Increased in yield due to Sulphur and Zinc nutrition might be ascribed to their fundamental metabolic role in plant, particularly, in nodulation and biological nitrogen fixation and carbohydrate metabolism Blevins, 1999 [17], Jyung *et al.* 1975) [18]. Consequently, the yield contributory characters were increased (as discussed earlier). This might be reason for improvement in seed yield. The results of this study are corroborated by those of several investigators H. K. Patel *et al.* (2014) [3], Khan K *et al*. (2018) [5], P.S. Sangwan and M. Raj (2004) [6], Hema Deshlahar *et al*. (2019) [2]

Growth and yield contributory characters

The results relating to growth parameters described in Table 1 and 2 i.e., plant height, root length, number of branches and sub branches $plant^{-1}$ and yield contributory characters as in Table 3 and 4 as nodule number, pod number and seed test weight are finally manifested into yield, and all these characters exert favorable and positive influence on yield. Increase in growth and yield contributory characters to a level of statistical significance might be due to the fact that native soil of experimental field was deficient in Sulphur and Zinc and application of these nutrient elements might by helpful in the growth and development of these characters. Sulphur nutrition of crops under dry land conditions effects water economy by regulating the opening and closing of stomata and tones up the translocation of water through xylem vessels through the process of coupled phosphorylation and di-phosphorylation controlled by ATP. Thus, application of potash under rain fed conditions might have helped in increasing the growth and yield contributory characters. H. K. Patel *et al.* (2014) [3] from the study it could be concluded that yield, quality parameters and post-harvest soil nutrient status were significantly influenced by application of Sulphur and Zinc fertilizations with PSB inoculation. Application of 20 kg S ha-1 with 25 kg P_2O_5 ha-1+ PSB was produced more yield. From the yield and economic point of view, it is concluded that for securing higher yield the chickpea crop should be fertilized with 20 kg S ha-1 and 25 kg P_2O_5 ha-1+ PSB and also maintained soil health.

Conclusion

Based on one our one year of study, it may be concluded that the combined application of Sulphur 25 kg ha^{-1} with Zinc 15 kg ha^{-1} increased the growth, yield attributes in chickpea compared with the other levels. Application of Sulphur 25 kg ha^{-1} with Zinc 15 kg ha^{-1} is sufficient to sustain the productivity of chickpea in under rainfed condition.

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