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Effect of sulphur and zinc on growth, yield, quality and economics of cowpea (*Vigna unguiculata* L.)

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Abstract
An experiment was conducted at ICAR-KVK, Kalaburagi during the *Kharif* season of 2022. The Experiment was laid out in RCBD with Eight treatments which were replicated thrice. The experimental results revealed that, soil application of (RDF) + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate through chemical fertilizers recorded significantly higher seed yield (1395 kg ha^{-1}), stover yield (2778 kg ha^{-1}) and economics parameters like, net returns (58793 Rs ha^{-1}) and B:C ratio (2.28). However, higher plant height (65.5 cm), total dry matter production (26.9 g plant^{-1}), and protein content (21.5%) was recorded. Which was on par with (RDF) + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate. In contrast lower value for growth, yield and quality parameters recorded in absolute control. Hence, for effective management of sulphur and zinc, the application of RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate was recommended.

Keywords: Cowpea, growth, yield, quality, economics, sulphur, zinc

1. Introduction
Cowpea (*Vigna unguiculata* L.) is one of the important *kharif* pulse crop in India. It belongs to Fabaceae and sub family Faboideae. It is originated in Sub-Saharan Africa. It is one of the most important vegetable crops grown as pulse, vegetable and fodder. The cowpea has often been referred to as “poor man’s meat” due to the high levels of protein found in the seeds and leaves and considered one of the most ancient human food sources and has probably been used as a crop plant since Neolithic time. Nutritional value per (100 g), Protein 23.52 g, Energy 336 kcal, Carbohydrates 60.03 g, Sugars 6.9 g, Dietary fiber 10.6 g, Fat 1.26 g, Water 11.95 g, Vitamins and Minerals. Cowpea is a vital multipurpose grain legume extensively cultivated in arid and semiarid tropics. It is an important source of nutrients and provides high quality, inexpensive protein diet based on cereal grains and starch foods. Cowpea is a good source of food, fodder and vegetables. In India pulses are grown nearly in 25.43 m ha with an annual production of 17.28 m t and a median productivity of 679 kg/ha).

In Rajasthan, the realm under pulses is 47.54 lakh ha with an annual production of 32.54 lakh mt and an average productivity of 684 kg/ha and also the cowpea is grown chiefly in central and peninsular regions of India. It is mainly grown in Uttar Pradesh, Punjab, Haryana, Rajasthan and Madhya Pradesh. In Rajasthan, vegetable cowpea is grown an area of 1.18 lakh ha with the production of 0.62 lakh tonnes and productivity of 529 kg/ha (Anonymous, 2016). [1] In Rajasthan, vegetable cowpea is grown in very small areas especially in summer and rainy season. In Karnataka, the crop is grown in an area of 1.5 million hectares with a production of 0.49 million tonnes. The productivity of cowpea in Karnataka is low (420 kg ha^{-1}) as compared to the national productivity of 567 kg ha^{-1}. This clearly indicates there is necessity to identify the reasons for low productivity in India in general and Karnataka in particular.

Sulphur is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium in crops and an essential element for plant growth particularly for legumes crops which play an important role in plant metabolism system, Sulphur containing amino acids (cystine, cysteine and methionine) and promotes nodulation in legumes.

Zinc which is important for growth and reproduction in plants, animals and humans, is one of the seventh essential micronutrients. In plants, it plays a key role during physiological growth, DNA stabilization, gene expression, enzyme activity, protein synthesis and improved chlorophyll function.

2. Materials and Methods
The experiment was conducted at ICAR-Krishi Vigyan Kendra farm, Kalaburagi (Karnataka)

during *Kharif* season, 2022. Kalaburagi is situated in the North Eastern Dry Zone (Zone-2) of Karnataka between 17º 34' N latitude and 76º 79' E longitude with an altitude of 478 meters above the mean sea level.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments *viz*., T_1 – Absolute control, T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}), T_3 - RDF + 10 kg ha^{-1} sulphur, T_4 - RDF + 20 kg ha^{-1} sulphur, T_5 - RDF + 5 kg ha^{-1} zinc sulphate, T_6 - RDF + 10 kg ha^{-1} zinc sulphate, T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate and T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate and were replicated thrice. The soil has a clayey texture, moderately alkaline pH of 8.11, low EC of 0.28 dSm^{-1}, low amount of soil organic carbon (4.32 g kg^{-1}) and calcium carbonate (3.12%). The soil available nitrogen content was low (229.14 kg ha^{-1}), phosphorus availability was medium (29.17 kg ha^{-1}), potassium content was high (342.15 kg ha^{-1}) and sulphur content was low (15.67 kg ha^{-1}). DTPA extractable zinc, iron, copper and manganese contents were 0.53, 2.46, 1.20 and 3.62 respectively and available boron 0.26 mg kg^{-1}.

The treatments were consisting of different rate of soil application of sulphur and zinc with the recommended dose of fertilizer (see table 1 for further details). The cowpea variety C-152 was selected for the study. Seeds were sown at 45 cm × 10 cm spacing in ridges and furrows on July 16, 2022 and harvested on October 26, 2022. From randomly tagged five plants, plant height was measured from the base of the plant at ground surface up to growing tip of the plant. Biometric observations were recorded at 30, 60 DAS and at harvest. The observation on seed yield was recorded at harvest.

3. Results and Discussion

3.1 Effect of sulphur and zinc on growth parameters

3.1.1 Plant height

Plant height at various growth stages was significantly effected by an application of different levels of sulphur and zinc (Table 1). Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} as basal was shown greater plant height (18.4 cm, 49.0 cm and 65.5 cm respectively, at 30, 60 DAS and at harvest) and it was found on par with RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (17.3 cm 47.4 cm and 63.5 cm respectively, at 30, 60 DAS and at harvest). Whereas, lower plant height was recorded in absolute control. Application of sulphur and zinc with conventional fertilizer through soil had an enhanced photosynthetic and other metabolic activities. Which lead to increase in various plant metabolites responsible for cell division and elongation effect on growth of cowpea. “This may be due to added sulphur enhanced the synthesis of chlorophyll content in the leaves.” Similarly, zinc play an essential role in plant growth through the biosynthesis of endogenous hormones, which is responsible for promotion of plant growth, and role in cell division, meristematic activity of plant tissue and expansions of cells. Nitrogen increased the proportion of protoplasm to cell wall material. An increase in size of cell, which expressed morphologically increased in plant height. Similarly, the higher values of plant height were also reported by Kumawat *et al*. (2014) [2] and Singh *et al*. (2015) [3].

3.1.2 Number of branches per plant

Number of branches per plant at various growth stages was significantly effected by an application of different levels of sulphur and zinc (Table 2). Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} as basal was shown more number of branches per plant (6.5, 12.8 and 17.4 respectively, at 30, 60 DAS and at harvest) and it was found on par with RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (6.2, 12.2 and 17.0 respectively, at 30, 60 DAS and at harvest). Whereas, less number of branches per plant was recorded in absolute control. Similar results were reported by Singh *et al*. (2016) [4].

3.1.3 Total dry matter production

Total dry matter production at different growth stages was significantly effected by an application of different levels of sulphur and zinc (Fig. 1). Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} as basal was shown higher dry matter production (5.2 g plant^{-1}, 11.3 g plant^{-1} and 26.9 g plant^{-1} respectively, at 30, 60 DAS and at harvest). and it was found on par with RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (5.0 g plant^{-1}, 10.9 g plant^{-1} and 26.4 g plant^{-1} respectively, at 30, 60 DAS and at harvest). However, lower dry matter production was recorded in absolute control. The accumulation of dry matter determines that, how quickly plants grow. The accumulation of dry matter may have an impact on the economic output. Due to varying rates of nutrient input, each plant produced considerably variable amounts of dry matter. Crop dry matter production depends on the plant photosynthetic capacity which in turn depends on the accumulation of dry matter in leaves and stem. Higher dry matter production was recorded as a result of greater plant height and number of branches per plant. An application of different levels of sulphur and zinc with conventional fertilizers significantly increased the dry matter production in cowpea crop. The same findings reported by Jha *et al*. (2015) [5] and Singh *et al*. (2015) [3].

3.2 Effect of sulphur and zinc on yield

Significant differences were observed in yield and yield components *viz*., number of pods per plant, number of seeds per pod, test weight, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) due to soil application of different levels of sulphur and zinc. (Table 3&4).

3.2.1 Number of pods per plant

Number of pods plant^{-1} differed significantly due to soil application of sulphur and zinc. The number of pods produced by each plant ranged from 9.8 to 17.4 pods. Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} recorded higher number of pods plant^{-1} (17.4 pods plant^{-1}) and which was on par with the application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (16.7 pods plant^{-1}). However, lesser number of pods (9.8 pods plant^{-1}) was obtained in the treatment absolute control. An increase in total number of pods per plant might be due to adequate supply of plant nutrients during the cowpea growth stages, which leads to good growth and development of the crop. Hence, it leads to an increase in the number of pods per plant in cowpea crop. The similar results showed by Das *et al*. (2017) [6] and Duhan *et al*. (2018) [7].

3.2.2 Number of seeds per pod

Number of seeds pod^{-1} varied significantly due to treatment effects. The number of seeds produced by each pod ranged from 8.1 to 14.9 seeds per pod. Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} recorded higher number of seeds pod^{-1} (14.9 seeds pod^{-1}) and which was on par with the application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (14.2 seeds pod^{-1}). However, the least number of seeds per pod was obtained (8.1 seeds pod^{-1}) in the treatment absolute control. An increase in total number of seeds per pod might be due to good length of pods which accumulates more number of seeds per pod in cowpea crop. The results are similar with the findings by Usman *et al*. (2014) [8].

3.2.3 Test weight (g)

No significant difference was observed among the various treatments for test weight at harvest. However, a numerically higher test weight (12.8 g) was recorded in treatment with an application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} compared to other treatments. In comparison, a numerically lower test weight was recorded (11.7 g) in the absolute control.

3.2.4 Seed yield (kg ha^{-1})

Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} significantly recorded higher seed yield (1395 kg ha^{-1}) and which was on par with the application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (1308 kg ha^{-1}). However, the lower seed yield (744 kg ha^{-1}) was obtained in the treatment absolute control. Sulphur and zinc increased cowpea seed yield, it is mainly because of increase in growth of plant parts and metabolic process, such as photosynthesis leads to higher photosynthates accumulation and translocation to the economic parts of the plant. The similar results shown by Deshbharatar *et al*. (2010) [9] and Goyal *et al*. (2010) [10].

3.2.5 Stover yield (kg ha^{-1})

The stover yield differed significantly due to treatment effects. An application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} significantly obtained higher stover yield (2778 kg ha^{-1}) and which was on par with an application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} (2681 kg ha^{-1}). Whereas, the lower stover yield (1202 kg ha^{-1}) was recorded in the treatment absolute control. Maximum stover yield production it may probably due to the fact that sufficient availability of plant nutrients helps to plant growth and development of cowpea crop and enhanced the target activity which leads to biological production of crop. Similar findings reported by Mahilane and Singh (2018) [11].

3.2.6 Harvest index

Harvest index did not differ significantly due to treatment effects and it varies from 32.79 to 38.23%. However, the treatment absolute control recorded maximum harvest index (38.23%). While, minimum harvest index was recorded (32.79%) with the application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}.

3.3 Effect of sulphur and zinc on quality

3.3.1 Protein content (%)

Protein content was increased due to soil application of different levels of sulphur and zinc (Table 3). Higher protein content (21.5%) was recorded with an application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} and which was on par with an application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}. However lower protein content was recorded in the absolute control. Increase in protein content with an application of higher doses of sulphur might be due to increased root activity and translocation of higher nitrogen and sulphur resulting in the synthesis of more sulphur containing amino acids such as methionine, cysteine and cystine. The possible explanation for such enhancement in protein content was due to more supply of nitrogen to crop through nitrogen fixation by nodules due to sulphur and zinc application which culminated to a greater extent of nitrogen content in seed resulting higher protein content. The similar findings revealed by Patel *et al*. (2014) [12] and Usman *et al*. (2014) [8].

3.4 Effect of sulphur and zinc on economics

Economics of cowpea was increased due to soil application of different levels of sulphur and zinc (Table 5). Application of RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} recorded higher cost of cultivation (Rs. 45832 ha^{-1}), gross returns (Rs. 104625 ha^{-1}), net returns (Rs. 58793 ha^{-1}) and B:C ratio (2.28). However, it was found on par with application of RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1} i.e., net returns (Rs. 54990 ha^{-1}) and B:C ratio (2.27). Whereas, lower results were recorded in the absolute control.

Table 1: Effect of different levels of sulphur and zinc on plant height at different growth stages of cowpea crop

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
T_1 - Absolute control	13.2	32.6	41.3
T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1})	14.6	38.4	50.7
T_3 - RDF + 10 kg ha^{-1} sulphur	15.6	41.3	58.1
T_4 - RDF + 20 kg ha^{-1} sulphur	16.3	43.3	59.0
T_5 - RDF + 5 kg ha^{-1} zinc sulphate	14.7	39.0	51.5
T_6 - RDF + 10 kg ha^{-1} zinc sulphate	15.1	39.3	53.2
T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate	17.3	47.4	63.5
T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate	18.4	49.0	65.5
S. Em. ±	0.39	1.22	1.66
CD @ 5%	1.18	3.69	5.04

Note: RDF – Recommended Dose of Fertilizer

Table 2: Effect of different levels of sulphur and zinc on number of branches $plant^{-1}$ at different growth stages of cowpea crop

Treatments	Number of branches per plant		
	30 DAS	60 DAS	At harvest
T_1 - Absolute control	3.2	7.5	11.6
T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1})	3.5	9.1	13.8
T_3 - RDF + 10 kg ha^{-1} sulphur	4.6	11.1	15.1
T_4 - RDF + 20 kg ha^{-1} sulphur	4.8	11.5	15.4
T_5 - RDF + 5 kg ha^{-1} zinc sulphate	3.6	9.8	14.1
T_6 - RDF + 10 kg ha^{-1} zinc sulphate	3.8	10.2	14.5
T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate	6.2	12.2	17.0
T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate	6.5	12.8	17.4
S. Em. ±	0.16	0.41	0.52
CD @ 5%	0.48	1.25	1.59

Note: RDF – Recommended Dose of Fertilizer

Table 3: Effect of different levels of sulphur and zinc on number of pods per plant, number of seeds per pod, test weight (g) and protein content (%) of cowpea crop

Treatments	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Test weight (g)	Protein content (%)
T_1 - Absolute control	9.8	8.1	11.7	18.4
T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1})	11.2	10.8	11.9	19.6
T_3 - RDF + 10 kg ha^{-1} sulphur	13.4	12.9	12.1	20.5
T_4 - RDF + 20 kg ha^{-1} sulphur	14.6	13.4	12.2	20.8
T_5 - RDF + 5 kg ha^{-1} zinc sulphate	11.8	11.1	11.8	19.7
T_6 - RDF + 10 kg ha^{-1} zinc sulphate	12.4	11.6	11.9	19.9
T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate	16.7	14.2	12.5	21.1
T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate	17.4	14.9	12.8	21.5
S. Em. ±	0.40	0.36	0.38	0.18
CD @ 5%	1.22	1.08	NS	0.53

Note: RDF – Recommended Dose of Fertilizer

Table 4: Effect of different levels of sulphur and zinc on seed yield, stover yield and harvest index of cowpea crop

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
T_1 – Absolute control	744	1202	38.23
T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1})	1040	1897	35.41
T_3 - RDF + 10 kg ha^{-1} sulphur	1186	2238	34.63
T_4 - RDF + 20 kg ha^{-1} sulphur	1247	2406	34.13
T_5 - RDF + 5 kg ha^{-1} zinc sulphate	1073	1962	35.37
T_6 - RDF + 10 kg ha^{-1} zinc sulphate	1124	2006	35.91
T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate	1308	2681	32.79
T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate	1395	2778	33.42
S. Em. ±	34.88	94.17	2.84
CD @ 5%	105.80	285.64	NS

Note: RDF – Recommended Dose of Fertilizer

Table 5: Effect of different levels of sulphur and zinc on economics of cowpea crop cultivation

Treatments	Cost of Cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1 - Absolute control	33750	55800	22050	1.65
T_2 – RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1})	40388	78000	37612	1.93
T_3 - RDF + 10 kg ha^{-1} sulphur	41235	88950	47715	2.15
T_4 - RDF + 20 kg ha^{-1} sulphur	42082	93525	51443	2.22
T_5 - RDF + 5 kg ha^{-1} zinc sulphate	42263	80550	38287	1.90
T_6 - RDF + 10 kg ha^{-1} zinc sulphate	44138	84300	40162	1.90
T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate	43110	98100	54990	2.27
T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate	45832	104625	58793	2.28
S. Em. ±	-	-	1737.59	0.01
CD @ 5%	-	-	5270.42	0.04

Note: RDF – Recommended Dose of Fertilizer

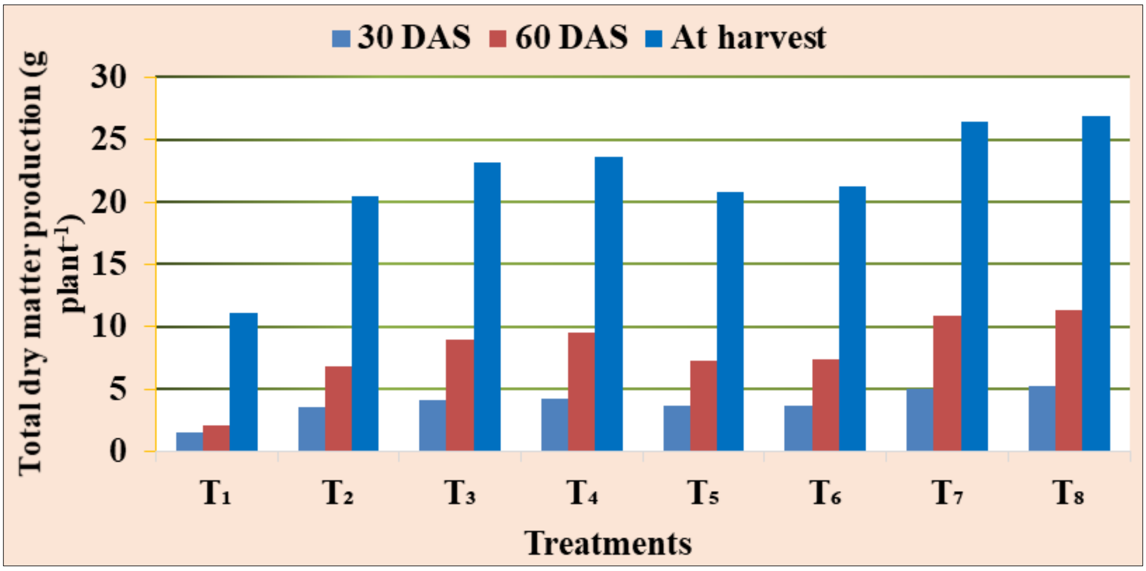

Fig 1: Effect of different levels of sulphur and zinc on total dry matter production (g plant^{-1}) at different growth stages of cowpea crop

4. Conclusion

Based on the results obtained under present investigation, recommended that soil application of sulphur (10 kg ha^{-1}) through bentonite sulphur @ 11 kg ha^{-1} + zinc (5 kg ha^{-1}) through zinc sulphate @ 15 kg ha^{-1} along with recommended dose of fertilizer was found superior not only in increasing the yield but also improved quality and economics of cowpea crop.

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