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Effect of Sulphur and zinc on nutrients balance sheet 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 removal of nitrogen by cowpea crop (88.03 kg ha^{-1}), phosphorus (20.87 kg ha^{-1}) potassium (58.70 kg ha^{-1}) sulphur (14.19 kg ha^{-1}) and zinc (0.171 kg ha^{-1}) was recorded. Which was on par with (RDF) + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate. In contrast lower value for removal of nutrients by cowpea crop 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, RDF, nitrogen, phosphorus, potassium, 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 17° 34' N latitude and 76° 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.

3. Results and Discussion

3.1 Effect of Sulphur and zinc on nutrients balance sheet

3.1.1 Balance sheet of Nitrogen

The initial status of nitrogen of the experimental site was 229.14 kg ha^{-1} (Table 1). The addition of nitrogen through fertilizer (25 kg ha^{-1}) and 10 tonne FYM (50 kg N) was common for all the treatments except for the treatment of absolute control (0 kg ha^{-1}). Total nitrogen removed by the crop was higher in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} (88.03 kg ha^{-1}) and the total nitrogen removed by the crop lower in the treatment absolute control (T_1) (32.59 kg ha^{-1}).

Higher net loss of nitrogen was observed (64.90 kg ha^{-1}) in the treatment (T_2) RDF and lower net loss of nitrogen was noticed (1.05 kg ha^{-1}) in the treatment (T_8) RDF +20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}. The results are in agreement with the findings of Kumawat *et al*. (2014) [2].

3.1.2 Balance sheet of Phosphorus

The initial status of phosphorus of the experimental site was 29.17 kg ha^{-1} (Table 2). The addition of phosphorus through fertilizer (50 kg ha^{-1}) and 10 tonne FYM (20 kg P) was common for all the treatments except for the treatment of absolute control (0 kg ha^{-1}). Total phosphorus removed by the crop was higher in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} (20.87 kg ha^{-1}) and the total phosphorus removed by the crop lower (5.30 kg ha^{-1}) in the treatment (T_1) *i.e.*, absolute control.

Higher net loss of phosphorus was observed (65.06 kg ha^{-1}) in the treatment (T_2) RDF and lower net loss of phosphorus was noticed (6.59 kg ha^{-1}) in the treatment (T_1) *i.e.*, absolute control. The results are in accordance with findings of Deshbharatar *et al*. (2010) [3].

3.1.3 Balance sheet of Potassium

The initial status of potassium of the experimental site was 342.15 kg ha^{-1} (Table 3). The addition of potassium through fertilizer (25 kg ha^{-1}) and 10 tonne FYM (50 kg K) was common for all the treatments except for the treatment of absolute control (0 kg ha^{-1}). Total potassium removed by the crop was higher in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} (58.70 kg ha^{-1}) and the total potassium removed by the crop lower in the treatment absolute control (T_1) (23.62 kg ha^{-1}).

Higher net loss of potassium was observed (102.06 kg ha^{-1}) in the treatment (T_2) RDF and lower net loss of potassium was noticed (51.38 kg ha^{-1}) in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}. Similar findings reported by Pandey (2018) [4].

3.1.4 Balance sheet of Sulphur

The initial status of sulphur of the experimental site was 15.67 kg ha^{-1} (Table 4). The addition of sulphur through fertilizer (T_3-10, T_4-20, T_7-10 and T_8-20 kg ha^{-1}) and 10 tonne FYM (8 kg 10 t^{-1}) was common for all the treatments except for the treatment of absolute control (0 kg ha^{-1}). Total sulphur removed by the crop was higher in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} (14.19 kg ha^{-1}) and the total sulphur removed by the crop lower (3.26 kg ha^{-1}) in the treatment (T_1) *i.e.*, absolute control.

Higher net loss of sulphur was recorded (8.7 kg ha^{-1}) in the treatment (T_4) RDF + 20 kg S ha^{-1} and lower net loss of sulphur was noticed (1.12 kg ha^{-1}) in the treatment (T_7) RDF + 10 kg S ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}. The similar results shown by Dawar *et al*. (2022) [5].

3.1.5 Balance sheet of Zinc

The initial status of zinc of the experimental site was 1.18 kg ha^{-1} (Table 5). The addition of zinc through fertilizer (T_5-5, T_6-10, T_7-5 and T_8-10 kg ha^{-1}) and 10 tonne FYM (0.15 kg 10 t^{-1}) was common for all the treatments except for the treatment of absolute control (0 kg ha^{-1}). Total zinc removed by the crop was higher in the treatment (T_8) RDF + 20 kg S ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} (0.171 kg ha^{-1}) and the total zinc removed by the crop lower (0.043 kg ha^{-1}) in the treatment (T_1) absolute control.

Higher net loss of zinc was recorded (9.759 kg ha^{-1}) in the treatment (T_6) RDF + 10 kg $ZnSO_4$ ha^{-1} and lower net loss of zinc was noticed in the treatment (T_4) RDF + 20 kg S ha^{-1} (0.722 kg ha^{-1}). The same findings reported by Kannan *et al*. (2014) [6].

Table 1: Balance sheet of available N in soil (kg ha^{-1}) as effected by sulphur and zinc application in cowpea

Treatments	Initial Nitrogen	Nitrogen applied through FYM	Nitrogen applied through Fertilizers	Total N	Removal of nitrogen by crop	Expected balance	Actual balance	Net Loss (-) or Net gain (+)
	(1)	(2)	(3)	(4) = 1+2+3	(5)	(6) = 4-5	(7)	(8) = 7-6
T_1	229.14	0	0	229.14	32.59	196.55	165.12	-31.43
T_2	229.14	50	25	304.14	57.04	247.10	182.20	-64.90
T_3	229.14	50	25	304.14	69.01	235.13	201.61	-33.52
T_4	229.14	50	25	304.14	74.29	229.85	205.14	-24.71
T_5	229.14	50	25	304.14	59.44	244.70	191.08	-53.62
T_6	229.14	50	25	304.14	62.66	241.48	194.29	-47.19
T_7	229.14	50	25	304.14	82.30	221.84	208.14	-13.70
T_8	229.14	50	25	304.14	88.03	216.11	215.06	-1.05

Note: FYM – Farm Yard Manure (N – 0.5%) applied at 10 t ha^{-1}
T_1 - Absolute control T_5 - RDF + 5 kg ha^{-1} zinc sulphate
T_2 - RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}) T_6 - RDF + 10 kg ha^{-1} zinc sulphate
T_3 - RDF + 10 kg ha^{-1} sulphur T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate
T_4 - RDF + 20 kg ha^{-1} sulphur T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate

Table 2: Balance sheet of available P in soil (kg ha^{-1}) as effected by sulphur and zinc application in cowpea

Treatments	Initial Phosphorus	Phosphorus applied through FYM	Phosphorus applied through Fertilizers	Total P	Removal of Phosphorus by crop	Expected balance	Actual balance	Net Loss (-) or Net gain (+)
	(1)	(2)	(3)	(4) = 1+2+3	(5)	(6) = 4-5	(7)	(8) = 7-6
T_1	29.17	0	0	29.17	5.30	23.87	17.28	-6.59
T_2	29.17	20	50	99.17	10.75	88.42	23.36	-65.06
T_3	29.17	20	50	99.17	14.64	84.53	27.36	-57.17
T_4	29.17	20	50	99.17	16.05	83.12	29.57	-53.55
T_5	29.17	20	50	99.17	11.42	87.75	24.32	-63.43
T_6	29.17	20	50	99.17	12.14	87.03	25.56	-61.47
T_7	29.17	20	50	99.17	19.35	79.82	32.36	-47.46
T_8	29.17	20	50	99.17	20.87	78.30	34.29	-44.01

Note: FYM – Farm Yard Manure (P – 0.2%) applied at 10 t ha^{-1}
T_1 - Absolute control T_5 - RDF + 5 kg ha^{-1} zinc sulphate
T_2 - RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}) T_6 - RDF + 10 kg ha^{-1} zinc sulphate
T_3 - RDF + 10 kg ha^{-1} sulphur T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate
T_4 - RDF + 20 kg ha^{-1} sulphur T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate

Table 3: Balance sheet of available K in soil (kg ha^{-1}) as effected by sulphur and zinc application in cowpea

Treatments	Initial Potassium	Potassium applied through FYM	Potassium applied through Fertilizers	Total K	Removal of Potassium by crop	Expected balance	Actual balance	Net Loss (-) or Net gain (+)
	(1)	(2)	(3)	(4) = 1+2+3	(5)	(6) = 4-5	(7)	(8) = 7-6
T_1	342.15	0	0	342.15	23.62	318.53	266.01	-52.52
T_2	342.15	50	25	417.15	37.61	379.54	277.48	-102.06
T_3	342.15	50	25	417.15	45.94	371.21	289.62	-81.59
T_4	342.15	50	25	417.15	49.40	367.75	293.22	-74.53
T_5	342.15	50	25	417.15	39.36	377.79	281.58	-96.21
T_6	342.15	50	25	417.15	40.99	376.16	283.38	-92.78
T_7	342.15	50	25	417.15	55.35	361.80	298.52	-63.28
T_8	342.15	50	25	417.15	58.70	358.45	307.07	-51.38

Note: FYM – Farm Yard Manure (K – 0.5%) applied at 10 t ha^{-1}
T_1 - Absolute control T_5 - RDF + 5 kg ha^{-1} zinc sulphate
T_2 - RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}) T_6 - RDF + 10 kg ha^{-1} zinc sulphate
T_3 - RDF + 10 kg ha^{-1} sulphur T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate
T_4 - RDF + 20 kg ha^{-1} sulphur T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate

Table 4: Balance sheet of available S in soil (kg ha^{-1}) as effected by sulphur and zinc application in cowpea

Treatments	Initial Sulphur	Sulphur applied through FYM	Sulphur applied through Fertilizers	Total S	Removal of Sulphur by crop	Expected balance	Actual balance	Net Loss (-) or Net gain (+)
	(1)	(2)	(3)	(4) = 1+2+3	(5)	(6) = 4-5	(7)	(8) = 7-6
T_1	15.67	0	0	15.67	3.26	12.41	8.22	-4.19
T_2	15.67	8	0	23.67	6.08	17.59	10.29	-7.3
T_3	15.67	8	10	33.67	9.83	23.84	20.62	-3.22
T_4	15.67	8	20	43.67	12.07	31.6	22.90	-8.7
T_5	15.67	8	0.75	24.42	7.00	17.42	12.56	-4.86
T_6	15.67	8	1.50	25.17	8.05	17.12	14.38	-2.74
T_7	15.67	8	10	33.67	11.84	21.83	20.71	-1.12
T_8	15.67	8	20	43.67	14.19	29.48	22.95	-6.53

Note: FYM – Farm Yard Manure (S – 0.08%) applied at 10 t ha^{-1}
T_1 - Absolute control T_5 - RDF + 5 kg ha^{-1} zinc sulphate
T_2 - RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}) T_6 - RDF + 10 kg ha^{-1} zinc sulphate
T_3 - RDF + 10 kg ha^{-1} sulphur T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate
T_4 - RDF + 20 kg ha^{-1} sulphur T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate

Table 5: Balance sheet of available Zn in soil (kg ha^{-1}) as effected by sulphur and zinc application in cowpea

Treatments	Initial Zinc	Zinc applied through FYM	Zinc applied through Fertilizers	Total Zn	Removal of Zinc by crop	Expected balance	Actual balance	Net Loss (-) or Net gain (+)
	(1)	(2)	(3)	(4) = 1+2+3	(5)	(6) = 4-5	(7)	(8) = 7-6
T_1	1.18	0	0	1.18	0.043	1.137	0.29	-0.847
T_2	1.18	0.15	0	1.33	0.069	1.261	0.38	-0.881
T_3	1.18	0.15	0	1.33	0.106	1.224	0.44	-0.784
T_4	1.18	0.15	0	1.33	0.118	1.212	0.49	-0.722
T_5	1.18	0.15	5	6.33	0.093	6.237	1.16	-5.077
T_6	1.18	0.15	10	11.33	0.111	11.219	1.46	-9.759
T_7	1.18	0.15	5	6.33	0.156	6.174	1.20	-4.974
T_8	1.18	0.15	10	11.33	0.171	11.159	1.51	-9.649

Note: FYM – Farm Yard Manure (Zn – 15.43 mg kg^{-1}) applied at 10 t ha^{-1}
mg kg^{-1} x 2.24 = kg ha^{-1}
T_1 - Absolute control T_5 - RDF + 5 kg ha^{-1} zinc sulphate
T_2 - RDF (25:50:25; N: P_2O_5: K_2O: kg ha^{-1}) T_6 - RDF + 10 kg ha^{-1} zinc sulphate
T_3 - RDF + 10 kg ha^{-1} sulphur T_7 - RDF + 10 kg ha^{-1} sulphur + 5 kg ha^{-1} zinc sulphate
T_4 - RDF + 20 kg ha^{-1} sulphur T_8 - RDF + 20 kg ha^{-1} sulphur + 10 kg ha^{-1} zinc sulphate

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 in increasing the removal of nutrients by cowpea crop.

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