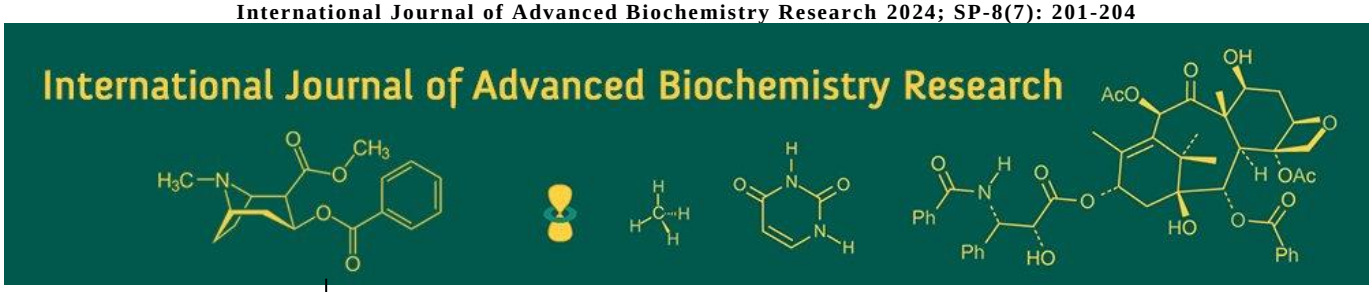

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Effect of sulfur and zinc nutrition on growth and yield of green gram (*Vigna radiata* L.)

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Abstract
The field experiment was conducted at Research Farm of Agricultural Research Sub Station, Gonera, Kotputli during *Kharif* seasons of 2020 and 2021. The experiment comprising of 10th treatments combinations of zinc and sulphur nutrition was laid out in randomized block design and replicated thrice. Both the years results showed that the application of T_4 - RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}significantly increased yield attributes like number of branches per plant, plant height, number of pods per plant, number of seeds per pod, effective nodules per plant and significantly higher seed (817 kg ha^{-1} and 933 kg ha^{-1}) and straw (1215 kg ha^{-1} and 1324 kg ha^{-1}) yield as compared to other treatments. However, treatment T_4 (RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}) remained statistical at par with treatment T_{10} (RDF + mixed fertilizer of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0.5% Zn) significantly increased seed and straw yield of green gram over rest of the treatments. The maximum net return (Rs. 28688 and 34071 per ha) and B: C ratio (1.50 and 1.56) were recorded under the treatment of T_4 (RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}) as compared to other treatments.

Keywords: Sulphur, zinc, moong, plant nutrition

Introduction
Green gram (*Vigna radiate* L.) is a major of the pulse crop of India that belongs to the family of Leguminosae. It has more amounts of proteins, minerals, nutrients, essential amino acids and fiber contents better digestibility than any other pulse crop (Tabassum *et al.*, 2010) [12]. India's main agricultural exports pulse crop of green gram due to high economic an1d commercial values. As a leguminous crop, green gram will benefit farmer's economies and enhance soil fertility. Chemical fertilizers are now vital to existing agricultural production methods, yet they have also been correlated to environmental and ecological issues. The loss of nutrients from agricultural fields through leaching and gaseous emissions is the main factors contributing to environmental pollution and climate change. Rajasthan, it is grown on an area of 3.41 thousand hectare with a production of 1.21 lakhs tones (Anonymous, 2022).
There is scope to enhance the productivity of Green gram by proper agronomic practices and fertilizers. Application of nutrient for increasing and exploiting genetic potential of the crop is considered as an efficient and economic method of supplementing the nutrient requirement. Application of sulphur will enhance the nutrient availability and in turn increases the productivity. Application of major nutrients NPK with sulphur was found to be advantageous and increases the productivity.
Sulphur is essential secondary plant nutrients, and key component of protein, it is necessary for the utilization of nitrogen. As a result, the formation of enzymes, vitamins, and chlorophyll, are dependent on its availability. It is essential part of amino acids *viz.* methionine, cystine and cysteine. This amino acid is present in plant about 90% (Tandon and Messick, 2002) [2]. Sulphur is also positively response to enhanced content of phosphorus, sulphur, and protein in grain yield. Sulphur increase crop yields and improve quality of produce, both of which are important for determining the market price. It is very important for legumes crops to fix atmospheric nitrogen; sulphur must be available to form the nodules necessary for nitrogen fixation. The positive response of sulphur found in legume crops has been reported by earlier authors Jat *et al.*, (2013) [6], Upadhyay, (2013) [14], Neha, and Dawson, (2023) [8].

Zinc (Zn) is an essential micronutrient that plays key roles in plant life. Zinc deficiency is the major problem of micronutrient deficiency found everywhere in the world. In Rajasthan, while some soils are capable of supplying adequate amounts for crop production with addition of zinc fertilizers. Zinc is also influence as growth hormones, elongation of the nodes and in the chloroplast and starch regain is effective (Mishra *et al.*, 2022) [7]. Zinc is essential mineral nutrients for both the plants and animals because it is make a structural constituent and regulatory co-factor in enzymes activation and proteins involved in many biochemical pathways (Alloway, 2009) [1].

Material Methods

The experiment was conducted at Agriculture Research Sub Station, Gonera under College of Agriculture, Kotputli, Jaipur during *Kharif* season in 2020 and 2021. The soil was Haplustepts, sandy loam in texture having pH 8.1, EC 0.67 dS m^{-1}, organic carbon 0.3 g kg^{-1}, available nitrogen 180 kg ha^{-1}, available phosphorus 23 kg ha^{-1}, and available potassium 123 kg ha^{-1}, available sulphur 6.0 mg/kg and zinc 1.5 mg/kg. The experiment comprising of 10 treatments combinations of zinc and sulphur nutrition was laid out in randomized block design and replicated thrice. The 10 treatments consist of T_1- RDF(15 kg N and 40 kg P), T_2- RDF + S@20 kg ha^{-1} (S 90% P), T_3- RDF + Zn@5 kg ha^{-1} (Zn 33%), T_4- RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}, T_5- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} (ready mix 67%S + 14%Zn),T_6- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.25% Zn, T_7- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.50% Zn, T_8- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} (ready mix 67%S + 14%Zn), T_9- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0.25% Zn, T^{10}- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0. 5% Zn. The growth parameters were recorded for number of branches per plant, plant height, number of pod per plant, number of seed per pod, number of effective nodules per plant. The economics of treatment was worked out in terms of net returns and the Benefit/Cost (B: C) ratio on prevailing market price of inputs and output. The net return was calculated by subtracting cost of cultivation for each treatment from gross return arrived at from the economic yield.

Result and Discussion

All the data of growth, yield and economics revealed that study showed significant variation when treated with different sources of sulfur and zinc nutrients which were either applied individually or in combination.

Growth attributes

Growth attribute and nodules of green gram crop as influenced by sulfur and zinc nutrition presented in (table 1). Both the year results showed that application of T_4 - RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}significantly increased yield attributes, number of branches per plant(12.6 and 13.1), plant height (53.7 and 55.2), number of pods per plant (30.1 and 32.6), number of seeds per pod (11.7 and 12.1), and effective nodules per plant (12.1 and 22.6) as compared to other treatments. This might be due to role of sulphur in the stimulation of cell division, the process of photosynthesis and also the conformation of chlorophyll. These results are harmonious with those of Chaudhary, *et al*., (2001) [4], Srivastava *et al*., (2006) [10], Chapirimatam, *et al*., (2022) [3].

Table 1: Effect of sulphur and zinc nutrition on yield of green gram

Treatment	Seed Yield (Kg ha^{-1})		Straw Yield (Kg ha^{-1})	
	2020	2021	2020	2021
T_1- RDF(15 kg N and 40 kg P)	603	718	887	929
T_2- RDF + S@20 kg ha^{-1} (S 90% P)	659	780	942	982
T_3- RDF + Zn@5 kg ha^{-1} (Zn 33%)	670	787	969	1005
T_4- RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}	817	938	1215	1324
T_5- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} (ready mix 67%S + 14%Zn)	666	783	945	1021
T_6- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.25% Zn	678	816	996	1038
T_7- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.50% Zn	685	836	1034	1082
T_8- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} (ready mix 67%S + 14%Zn)	678	798	1024	1056
T_9- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0.25% Zn	719	834	1066	1159
T_{10}- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0. 5% Zn	796	883	1150	1233
S. Em. +	32.38	33.66	47.69	54.90
CD(P=0.05)	94.97	98.74	139.89	161.01

Yield attributes

A perusal of data both the year data indicated that the effect of different dose of sulfur and zinc nutrition single as well as combination has significant effect on yield of green gram crop. Both the year results showed that application of T_4 - RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1} obtained significantly higher seed (817 kg ha^{-1} and 933 kg ha^{-1}) and straw (1215 kg ha^{-1} and 1324 kg ha^{-1}) yield as compared to other treatments. However, treatment T_4 (RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}) remained statistical at par with treatment T_{10} (RDF + mixed fertilizer of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0.5% Zn) significantly increased seed and straw yield of green gram over rest of the treatments. A similar result was found in the increase of yield can be caused by the application of zinc to increasing the enzymatic and physiological activities and the performance of many catalytic functions in the plant system, in addition to the transformation of carbohydrates, chlorophyll and protein synthesis. The increase in yield was mainly due to the increased rate of photosynthesis and carbohydrate metabolism influenced by sulphur application. The results obtained were consistent with the findings reported by Surendra Ram *et al*., (2018) [11] and Italiya *et al*., (2019) [5].

Economics of treatments

Data pertaining to economics of green gram was presented in the table 2. The maximum net return (Rs. 28688 and 34071) and B: C ratio (1.50 and 1.56) were recorded in both the year under the treatment T_4 (RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}) as compared to other treatments. The

economic and B:C ratio correlated with the increase in yield was mainly due to the increased rate of photosynthesis and carbohydrate metabolism influenced by combined application of sulphur and zinc application. The results found are consistent with the findings reported by Sindhuja *et al*., (2023) [9] and Neha, and Dawson (2023) [8].

Table 2: Effect of sulphur and zinc nutrition on mean economics of green gram

Treatment	Net Returns (Rs./ha)		B:C	
	2020	2021	2020	2021
T_1- RDF(15 kg N and 40 kg P)	18608	23581	1.12	1.21
T_2- RDF + S@20 kg ha^{-1} (S 90% P)	19845	25311	1.06	1.18
T_3- RDF + Zn@5 kg ha^{-1} (Zn 33%)	22108	27349	1.29	1.37
T_4- RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1}	28688	34071	1.50	1.56
T_5- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} (ready mix 67%S + 14%Zn)	19294	24751	0.98	1.10
T_6- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.25% Zn	19857	26321	1.00	1.16
T_7- RDF + mixed feriliser of S + Zn @ 15 kg ha^{-1} + Foliar spray of 0.50% Zn	20186	28053	1.02	1.24
T_8- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} (ready mix 67%S + 14%Zn)	18976	24371	0.92	1.04
T_9- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0.25% Zn	21684	27023	1.04	1.14
T_{10}- RDF + mixed feriliser of S + Zn @ 20 kg ha^{-1} + Foliar spray of 0. 5% Zn	25699	29291	1.23	1.24

Table 3: Effect of sulphur and zinc nutrition on number of branches per plant, plant height, number of pods per plant, number of seeds per pod and number of effective nodules per plant of green gram

Treatment	No. of branches/plant		Plant height (cm)		No. of pods/plant		No. of seeds/pod		No. of effective nodules/plant	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_1- RDF(15 kg N and 40 kg P)	9.7	10.3	44.8	45.6	22.7	23.6	9.4	10.0	18.6	19.7
T_2- RDF+S@20 kg ha^{-1} (S 90% P)	10.8	11.0	48.0	49.8	24.9	26.2	9.7	10.6	19.7	20.9
T_3- RDF+Zn@5 kg ha^{-1} (Zn33%)	11.1	11.8	49.4	51.2	26.3	28.3	10.2	11.2	20.8	21.6
T_4- RDF+S@20kg ha^{-1} + Zn@5 kg ha^{-1}	12.6	13.1	53.7	55.2	30.1	32.6	11.7	12.1	22.6	23.5
T_5- RDF+ mixed feriliser of S+Zn @ 15 kg ha^{-1} (ready mix 67%S+14%Zn)	10.9	11.1	48.2	48.8	24.3	27.6	10.1	10.6	19.9	20.6
T_6- RDF+ mixed feriliser of S+Zn @ 15 kg ha^{-1}+ Foliar spray of 0.25% Zn	11.1	11.4	49.2	50.9	25.3	28.4	10.4	10.8	20.4	21.4
T_7- RDF+ mixed feriliser of S+Zn @ 15 kg ha^{-1}+ Foliar spray of 0.50% Zn	11.4	11.9	50.2	51.3	27.0	29.3	10.7	11.2	21.3	21.6
T_8- RDF+ mixed feriliser of S+Zn @ 20 kg ha^{-1} (ready mix 67%S+14%Zn)	11.1	11.4	49.5	50.6	25.9	28.4	10.4	10.6	20.1	21.3
T_9- RDF+ mixed feriliser of S+Zn @ 20 kg ha^{-1}+ Foliar spray of 0.25% Zn	11.5	11.9	50.3	51.5	27.1	30.0	10.8	11.0	20.9	21.8
T_{10}- RDF+mixed feriliser of S+Zn @ 20 kg ha^{-1}+ Foliar spray of 0. 5% Zn	12.0	12.5	52.3	52.9	28.4	31.1	11.4	11.4	21.8	22.7
S. Em. +	0.35	0.35	1.12	1.26	0.66	0.85	0.24	0.28	0.44	0.49
CD(P=0.05)	1.04	1.03	3.28	3.70	1.95	2.48	0.71	0.81	1.29	1.43

Conclusion

It is concluded that application of application of T_4 - RDF + S@20kg ha^{-1} + Zn@5 kg ha^{-1} was found the most suitable dose of fertilizer to be adopted as it recorded higher performance in growth parameter, yield attributes and yield. It was also found economically productive during *Kharif* season under Rajasthan. The conclusions drawn are based on only two seasons of data, which requires further confirmation for recommendations.

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