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Growth, nodulation and yield of black gram (*Vigna radiata* L.) as influenced by sulphur and iron under sandy loam soil

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Abstract
A field experiment entitled "Performance of sulphur and iron on growth and yield of green gram [*Vigna radiata* (L.) under Jaipur agro-climatic conditions was conducted during *kharif* season of 2018 at the Crop Research Farm, Department of Agronomy, Suresh Gyan Vihar University, Jaipur Rajasthan. The experiment was laid down in randomized block design (RBD) with eight treatments which were replicated thrice for comparing the performance of variety SUBH-51conducted. Among all the treatment it was found that treatment T_8 recorded significantly highest plant height (54.81cm), number of root nodules plant^{-1} (73.82), dry weight plant^{-1} (21.54gm) number of branches plant^{-1} (7.13) grain yield (7.90 q ha^{-1}) and Stover yield (8.02 q ha^{-1}) over rest of the treatments but it was found statistically at par with the treatment T_5 i.e. (25 kg S ha^{-1} as $ZnSO_4$+1%$FeSO_4$ as foliar spray at 25 DAS) against minimum recorded in treatment T_1 i.e. control.

Keywords: Green gram, sulphur, iron, growth and yield

Introduction
Pulses are an important part of profitable agriculture because a large section of population relies on them as they are low priced source of proteins (Usman *et al.,* 2014) [16]. The protein from pulses is easily digestible, relatively cheaper and has higher biological values. The lysine rich protein of pulses are considered to supplement the deficiency of this amino acid in cereal dietaries and because of this pulses are called as "*poor man's protein*". (Ramamurthi *et al.,* 2012) [9].

Sulphur are one of the most important nutrients for all plants and animals and also a component of key enzymes and vitamin in the plant and is necessary for the formation of chlorophyll. In legumes sulphur is necessary for the efficient fixation of nitrogen by the plant. This makes sulphur of fundamental importance in the establishment and maintenance of legume-based improved pasture. Sulphur as the fourth major nutrient in increasing agricultural crop production after nitrogen, phosphorus and potassium. Sulphur is a constituent of essential amino acids *viz*., methionine, cysteine and cysteine-the building blocks of protein. Therefore, sulphur fertilization is considered as critical for seed yield and protein synthesis and for improvement in quality of produce in legumes through their enzymatic and metabolic effects (Bhattacharjee *et al.,* 2013) [2]. In addition, sulphur is required by the rhizobia bacteria in legumes including green gram for nitrogen fixation. Foliar application of Fe solutions is one of the most widely used methods for correcting Fe deficiency in many crops including legumes. This method of application usually circumvents the problems associated with Fe application to the soil. Goos and Johnson (2000) [3] reported that foliar sprays of Fe significantly reduced iron-deficiency chlorosis, while increased seed yield in soybean. Therefore, balanced fertilization of macro and micro nutrients particularly in combination is very important for proper growth, development and high yield production of crop plants including green gram (Sawan *et al.,* 2001) [15].

Although plenty of research has been conducted on balanced fertilization of sulphur and iron on legumes including green gram but there is limited written information available of improvement in growth and yield parameters of green gram in response to application of sulphur and iron through different sources (ZnSO4, SSP and FeSO4). Thus, the present investigation was undertaken with the objective to determine the effect of different sources of sulphur as well as foliar spray of iron on growth and yield of green gram.

Materials and Methods

The present investigation was undertaken during *kharif* season during 2018 under sandy loam soil condition at the Crop Research Farm, Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan). For the intended study 8 treatments *viz*., T_1 (control), T_2 (1.0% $FeSO_4$ as foliar spray at 25 DAS), T_3 (25kg S ha^{-1} as $ZnSO_4$), T_4 (25kg S ha^{-1} as SSP), T_5 (25kg S ha^{-1} as $ZnSO_4$+1.0% $FeSO_4$ as foliar spray at 25 DAS), T_6 (25kg S ha^{-1} as SSP+1.0% $FeSO_4$ as foliar spray at 25 DAS), T_7 (12.5kg S ha^{-1} as $ZnSO_4$+12.5kg S ha^{-1} as SSP) and T_8 (12.5kg S ha^{-1} as $ZnSO_4$+12.5kg S ha^{-1} as SSP+1.0% $FeSO_4$), were tested under three replications by using randomized block design (RBD). Observations were recorded on various growth parameters *viz*., plant height, root nodules, dry weight, branches $plant^{-1}$ as well as on grain yield q ha^{-1} and stover yield q ha^{-1}. Data on various growth and yield parameters were subjected to statistical analysis in order to draw valid results. Nutrient management was done through SSP, $ZnSO_4$ and $FeSO_4$. In addition, recommended dosage of nitrogen @ 20kg ha^{-1} was supplied through urea in two spilt doses.

Results and Discussion

Growth attributes

It is revealed from the Table 1 that growth parameters *viz*., plant height, number of nodules plant $^{-1}$, dry weight plant $^{-1}$ and number of branches $plant^{-1}$ were significantly influenced by varying treatment levels of ZnSo4, SSP and FeSO4 at different stages of crop growth i.e. 30, 45 and 60 DAS. Maximum plant height (14.39, 36.17 and 54.81 cm) at successive stages of crop growth (30, 45 and 60DAS) was recorded in treatment T8 (12.5kg S ha^{-1} through ZnSO4+12.5kg S ha^{-1} as SSP +1.0% FeSO4 as foliar spray at 25 DAS), which was statistically at par (13.48, 34.41 and 52.48cm) with treatment T_5 and significantly higher over other treatments. The results are in conformity with Singh *et al.* (2013) [12]. Treatment T_8 which comprises of 12.5kg S ha^{-1} as ZnSO4+12.5kg S ha-1 as SSP+1.0% FeSO4 as foliar spray at 25 DAS enumerated a significant impact on root nodules $plant^{-1}$ as well as observed maximum (30.05, 58.04 and 73.82) number of root nodules $plant^{-1}$ at all the successive stages of crop growth (30, 45 and 60 DAS) over rest of treatments used in present study. However, it remained at par (27.62, 53.95 and 72.77) with treatment T_5 (25kg S ha^{-1} as ZnSO4+ 1.0% FeSO4 as foliar spray at 25 DAS. These results are in conformity with Kumawat and Khangarot (2001) [4] who reported that sulphur and zinc present in ZnSO4 activates number of certain enzymes that helps the plants to attain more vigour in formation of nodules while on other side application of iron helps in rhizobial colonization in rhizosphere thus also results increase in number of nodules $plant^{-1}$. Significantly highest dry weight $plant^{-1}$ (7.00, 15.86 and 21.54g) taken at various stages of crop growth i.e., 30, 45 and 60 DAS was recorded in plots receiving 12.5kg S ha^{-1} as ZnSO4 in combination with 12.5kg S ha^{-1} as SSP and 1.0% FeSO4 as foliar spray at 25 DAS (T_8) which was statistically at par with treatment T_5 (25kg S ha-1 as ZnSO4+ 1.0% FeSO4 as foliar spray at 25 DAS) at 30DAS. Significantly the lowest dry weight $plant^{-1}$ (4.47, 9.10 and 14.38g) was registered by plots with zero application of ZnSO4, SSP and FeSO4 i.e., T_1 (control). Similar results were also reported by Shau *et al*., (2008) [14]. Maximum number of branches $plant^{-1}$ (2.26, 3.60 and 7.13) at 30, 45 and 60 DAS were observed in treatment T_8 (12.5kg S ha-1 as ZnSO4+12.5kg S ha-1 as SSP+1.0% FeSO4 as foliar spray at 25 DAS) against significantly minimum (1.57, 2.00, and 4.67) recorded in treatment T_1 (Control). These results are in the conformity with the result obtained by Piri *et al*., (2012) [7], Singh, P.K. *et al. (*2011) [11], Verma *et al.* (2014) [18].

Yield

Grain yield

It was observed from the Table-2 that grain yield was also significantly affected by various levels of ZnSO4, SSP and FeSO4. Significantly maximum grain yield (7.9 q ha^{-1}) was obtained in plots where 12.5kg S ha^{-1} as ZnSO4 in combination with 12.5kg S ha^{-1} as SSP along with 1% FeSO4 as foliar spray at 25 DAS was applied against significantly minimum (4.73 q ha^{-1}) observed from the plots with zero application of both sulphur and iron in the form ZnSO4, SSP and FeSO4 (control). The findings are in conformity with the work reported by Nadergoli *et al*, (2011) [6] who reported that maximum grain yield obtained in green gram may be due to increased metabolic process in plants due to sulphur application through ZnSO4 and SSP. In addition to sulphur, availability of zinc in zinc sulphate and iron in ferrous sulphate also helps in absorption of nutrients, which are expected to have efficient photosynthetic mechanism and better equipped for efficient translocation of photosynthates from source to sink, consequently resulting into increased grain yield Singh *et al*., (2011) [11], Quddus *et al*, (2011) [8] Singh, D.K *et al*. (2018) [10].

Stover yield

Perusal of the Table-2 indicates that application of different levels of ZnSO4, SSP and FeSO4 exhibited significant enhancement in stover yield of green gram. Significantly maximum stover yield (8.02 q ha^{-1}) was recorded in T8 treatment which consist of 12.5kg S ha^{-1} as ZnSO4 in combination with 12.5kg S ha^{-1} as SSP and 1.0% FeSO4 as foliar spray at 25 DAS against minimum (5.88 q ha^{-1}) that was recorded in control. Similar results were also reported by Khorgamy and Farin, (2009) [5] and Valenciano *et al*., (2010) [17] Surendra and Katiyar (2013) [13]. who reported that maximum stover yield obtained in green gram may be due to increased metabolic process in plants due to sulphur application through ZnSO4 and SSP.

Table 1: Performance of sulphur and iron on growth attributes of green gram (*Vigna radiata* L.)

Treatments		Plant height(cm)	Number of root nodules $plant^{-1}$	Dry weight(g)	Number of branches $plant^{-1}$
T_1	Control	42.91	51.98	14.38	4.67
T_2	1% $FeSO_4$ as foliar spray at 25 DAS	45.10	54.66	16.11	5.80
T_3	25 kg S ha^{-1} as $ZnSO_4$	49.51	60.08	16.45	6.07
T_4	25 kg S ha^{-1} as SSP	47.68	55.68	16.23	5.92
T_5	25 kg S ha^{-1} as $ZnSO_4$+1%$FeSO_4$ as foliar spray at 25 DAS	52.48	72.77	20.63	6.47
T_6	25 kg S ha^{-1} as SSP+1%$FeSO_4$ as foliar spray at 25 DAS	51.08	61.44	17.10	6.27
T_7	12.5kg S ha^{-1} as $ZnSO_4$ +12.5kg S ha^{-1} as SSP	51.83	69.87	18.37	6.33

T_8	12.5 kg S ha^{-1} as $ZnSO_4$ ha^{-1}+12.5 kg S ha^{-1} as SSP +1% $FeSO_4$ as foliar spray at 25 DAS	54.81	73.82	23.54	7.13
F- test		S	S	S	S
S. Ed.(±)		2.47	3.47	0.93	0.35
C. D. (P = 0.05)		5.29	7.44	2.00	0.78

Table 2: Performance of sulphur and iron on yield of green gram (*Vigna radiata* L.)

Treatments		Grain yield(q ha^{-1})	Straw yield (q ha^{-1})
T_1	Control	4.73	5.88
T_2	1% $FeSO_4$ as foliar spray at 25 DAS	5.43	6.53
T_3	25 kg S ha^{-1} as $ZnSO_4$	6.45	6.97
T_4	25 kg S ha^{-1} as SSP	5.47	6.86
T_5	25 kg S ha^{-1} as $ZnSO_4$+1%$FeSO_4$ as foliar spray at 25 DAS	7.79	7.72
T_6	25 kg S ha^{-1} as SSP+1%$FeSO_4$ as foliar spray at 25 DAS	6.79	7.20
T_7	12.5kg S ha^{-1} as $ZnSO_4$ +12.5kg S ha^{-1} as SSP	7.17	7.29
T_8	12.5 kg S ha^{-1} as $ZnSO_4$ ha^{-1}+12.5 kg S ha^{-1} as SSP +1% $FeSO_4$ as foliar spray at 25 DAS	7.90	8.02
F- test		S	S
S. Ed. (±)		0.34	0.38
C. D. (P = 0.05)		0.74	0.81

Conclusion

In light of the results gained from the present research. It is concluded that among different treatments, treatment T_8 which comprises of 12.5kg S ha-1 as ZnSO4 along with 12.5kg S ha-1 as SSP and 1% FeSO4 as foliar spray at 25 DAS was found to be most effective source of sulphur and iron. It results significant improvement in growth parameters as well as in grain and straw yield of green gram. The second best treatment level as a source of sulphur and iron was treatment T_5 (25kg S ha-1 as ZnSO4+1.0% FeSO4 as foliar spray at 25 DAS) that also enhanced significantly growth parameters as well grain and stover yield of green gram under study.

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