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Response of sulphur and iron fertilization on growth and yield of greengram (*Vigna radiata* L.)

Sudhanshu Suman, Rajesh Singh, Ekta Singh and Kalyani Dwivedi

Abstract
A field experiment was conducted during *zaid* 2021 at Crop Research Farm. Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.4), low in organic carbon (0.32%), available N (188.3 kg/ha), available P (34.5 kg/ha) and available K (87.5 kg/ha). The experiment was laid out in Randomized Block Design with Twelve treatments each replicated thrice on the basis of one year of experimentation. The treatments which are T_1 - Control (No sulphur + No iron), T_2 - No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_3 - No sulphur + 25 kg/ha $FeSO_4$ as basal dose application, T_4 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_5 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application, T_6 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying), T_7 - 40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_8 - 40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application, T_9 - 40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying), T_{10} - 40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_{11} - 40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application and T_{12} - 40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying)used. The results showed that application of 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha FeSO4 as basal dose application recorded maximum higher plant height (48.53 cm), number of nodules per plant (30.16), number of branches per plant (5.93), plant dry weight (10.69 g/plant), crop growth rate (10.08 g/m^2/day), number of pods per plant (36.07), number of seeds per pod (12.07), seed yield (1421.00 kg/ha), stover yield (3306.00 kg/ha) and harvest index (30.06%) as compared to other treatments.

Keywords: Greengram, sulphur, iron fertilization, growth parameters and yield attributes

Introduction
Greengram [*Vigna radiata* (L.) Wilczek.] Commonly known as mungbean or goldengram is one of the most important short-duration pulse crops grown in India. According to de Candolle (1886), Vavilov (1926) and Zukoviskij (1962) [5, 21, 25], greengram originated in the Indian sub-continent. Greengram is an important legume crop of Asian origin and is widely cultivated in the countries of Asia, Australia and Africa continents (Yang *et al*. 2008) [24]. It is a high protein legume (23-24%), occupies 14% of total pulses area and 7% of total pulse production in India. It ranks third among all pulses grown in India after chickpea and pigeonpea. Pulse crops play an important role in Indian agriculture and India is the largest producer and consumer of pulse in the world. Pulses contain a high percentage of quality protein nearly three times as much as cereals. Greengram is a self-pollinated crop and is an important grain legume of the tropical area. It belongs to the Family Fabaceae (or, Leguminosae) and sub-Family Papilionaceae. Pulses are an important part of profitable agriculture because a large section of population has to rely on this as it is low priced source of protein (Usman *et al*. 2007) [22].

Pulse crop, greengram [*Vigna radiata* (L.) Wilczek] every 100 g of edible portion of mungbean seed contains 75 mg calcium, 4.5 mg phosphorus, 24.5 g protein and 348 K Cal energy (Meena *et al*. 2013) [10]. 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) [11]. A balanced fertilization of macro and micro nutrients is very important for high yield and high quality products (Sawan *et al*. 2001) [13]. Mungbean is considered as poor man's meat as it contains approximately triple amount of protein as compared to rice. It synthesizes nitrogen in symbiosis with rhizobia and improves soil fertility by adding 20-25 kg N per hectare and biomass of soil. Mungbean has

more protein contents and better digestability than any other pulse crop (Tabassum *et al*. 2000) [20]. The residue of greengram is also used as feed for animals and enhances the soil fertility (Asaduzzaman. 2008) [1].

In year 2106-17 the total pulse grown on 238.56 lakhs hectare and production of India was 18.25 million tonnes with productivity of 765 kg/ha. India is the largest producer and consumer of pulse in world accounting for 25% of globule production and 50% consumption (Saraswati *et al*. 2004) [12]. Greengram occupies 30.53 lakh hectare area and contributes 15.09 lakh tonnes in pulsr production in the country (Statistical year book India, 2016) [17]. At global level India share prime position in mungbean production. In India, it is cultivated over a wide range of climatic conditions in the states of Maharashtra, Andhra Pradesh, Rajasthan, Odisha, and Bihar. Rajasthan is one of the major mungbean growing states of the country. Whereas, potential yield level of available improved varieties of mungbean varied between 1200 to 1600 kg/ha (Meena *et al*. 2013) [10].

Sulphur is considered as the fourth and essential major nutrient in increasing agricultural crop production after nitrogen, phosphorus and potassium because of its role is synthesis of proteins, vitamins, enzyme and flavoured compounds in plant. A bout 90% of plant sulphur is present in amino acid *viz*. Methionine (21% S), cysteine (26% S) and cysteine (27% S) (Tandon *et al*. 2002) [19]. These amino acids are the building blocks of protein. It has a role to play in increasing chlorophyll formation and aiding photosynthesis (Marschener. 1986) [8] and due to this sulphur is crucial for pulse crops. Sulphur also enhances quality of grains by increasing its nutritional values. Sulphur fertilization is considered as critical for seed yield, protein synthesis and for the quality improvement of economic produce in legumes through their enzymatic and metabolic effects (Bhattacharjee *et al*. 2013) [3]. There are many sources of sulphur available. One of the source of sulphur is the organic matter that helps in enriching the sulphur in soils naturally. Other sources of sulphur are rainfall and some. Some readily available sources include ammonium sulphate (24% S), potassium sulphate (17.6% S), gypsum (16.8% S) and zinc sulphate (17.8% S) (McCauley *et al*. 2009) [9]. Elemental sulphur is totally unavailable to plants. It must be oxidized by soil microbes to sulphate (SO_4-S) before it becomes available to crops. Gypsum has been found either superior or equal to other S containing fertilizers in pulse crops (Kumar *et al*. 2014) [7]. Single superphosphate is a multi-nutrient fertilizer containing 7% P, 12% S and 21% Ca accounts for about half of total S added through important fertilizers in India. Sulphur uptake by several crops revealed that the highest sulphur requirement (12 kg/tonne of yield) has been attributed to oilseeds followed by pulses (8 kg/tonne), millets (5-8 kg/tonne) and cereals (3-4 kg/tonne) (Tandon. 1986) [18].

Iron (Fe) is one of the essential micronutrient that enhances plant growth and reproduction (Welch. 1995) [23]. Iron was the first nutrient element discovered as essential for plant life. In the plant system, iron plays an important role in a series of metabolic activities involving respiratory enzymes and various photosynthesis reactions. Iron also plays an important role in legumes including green gram for nodule formation and nitrogen fixation. Iron has been considered to be associated with chlorophyll formation because its deficiency in the plant system results in foliar chlorosis. Foliar application of Fe solutions is one of the most widely used methods for correcting Fe deficiency in many crops. This method of application usually circumvents the problems associated with Fe application to the soil. Bera *et al.* (2015) [2], reported that foliar sprays of Fe significantly reduced iron deficiency chlorosis. 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) [13].

Materials and Methods

The experiment was carried out during *Zaid* season 2021 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj (U.P.), which is situated at 25° 24' 33" N latitude, 81° 51' 11" E longitude and 98 m altitude above the mean sea level. During *zaid* season 2021 on sandy loam soil soil, having nearly neutral in soil reaction (pH 7.4), organic carbon (0.32%), available nitrogen (188.30 kg/ha K), available phosphorus (34.5 kg/ha) and available potassium (87 kg/ha). The climate of the region is semi- arid subtropical. Treatments comprised of T_1 - Control (No sulphur + No iron), T_2 - No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_3 - No sulphur + 25 kg/ha $FeSO_4$ as basal dose application, T_4 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_5 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application, T_6 - 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying), T_7 - 40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_8 - 40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application, T_9 - 40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying), T_{10} - 40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS, T_{11} - 40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application and T_{12} - 40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying).These were replicated thrice and experiment was laid out in Randomized Block Design. Pre harvest observation *viz.* Plant height, number of nodules per plant, number of branches per plant, dry weight, crop growth rate (CGR) and relative growth rate (RGR). Post-harvest observation *viz.* number of pods per plant, number of seeds per pod, test weight, seed yield, stover yield and harvest index were also recorded to find out the best treatment combination for maximum yield of greengram.

Results and Discussion

Growth parameters and yield attributes

Effect of sulphur

The application of different sources of sulphur differed significantly with respect to growth and yield attributes of greengram. The growth parameters, yield attributes and yield increased with application of gypsum and single super phosphate (1:1) at same dose of sulphur and time of application. Growth and yield attributes *viz*. Plant height, number of nodules per plant, number of branches per plant, dry weight, crop relative rate, number of pods per plant, number of seeds per pods, seed yield, stover yield and harvest index increased significantly in treatment 5 (20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25

kg/ha $FeSO_4$ as basal dose application). The maximum plant height (48.53 cm) at 60 DAS, maximum dry weight (10.69 g) at 60 DAS, maximum crop growth rate (10.08 g/m2/day) at 30-45 DAS, maximum number of nodules (30.16) at 45 DAS, maximum number of branches per plant (5.93) at 60 DAS, maximum number of pods per plant (36.07), maximum number seeds per pod (12.17), seed yield (1421.00 kg/ha), stover yield (3306.00 kg/ha) and maximum harvest index (30.06) were recorded in treatment 5 with 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application. However, maximum relative growth rate (0.082 g/g/day) at 15-30 DAS and maximum test weight (37.03 g) were found to be non-significant in treatment 5 with application of 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application (Table 1. And Table 2.). These results obtained might be due to the important role of sulphur in energy transformation, activation of number of enzymes and also in carbohydrate metabolism. These results in close agreement with the findings of Sharma *et al.* (2001) and Budhar *et al.* (2001) [16, 4]. These results obtained might be ascribed to process of tissue differentiation from somatic to reproductive meristematic activity and development of floral primordial might have increased with increasing sulphur levels, resulting in more number of flowers and longer pods and higher grains yield. Increase in growth parameter may be due to cell division, enlargement and elongation resulting in overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the effect of sulphur application. These results are in agreement with the finding of Singh *et al.* (1998) [14].

Table 1: Response of sulphur and iron fertilization on growth parameters of greengram

S.No.	Treatment combinations	Plant height (cm) At 60 DAS	Number of nodules per plant At 45 DAS	Number of branches per plant At 60 DAS
1.	Control (No sulphur + No iron)	43.83	20.72	4.20
2.	No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	45.50	23.33	4.53
3.	No sulphur + 25 kg/ha $FeSO_4$ as basal dose application.	46.50	25.14	4.60
4.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS.	47.97	29.34	5.73
5.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application	48.53	30.16	5.93
6.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	46.97	27.73	5.20
7.	40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	47.10	27.42	5.33
8.	40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application.	47.80	28.72	5.67
9.	40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	46.83	26.75	5.07
10.	40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	47.57	28.10	5.53
11.	40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application.	48.10	29.78	5.87
12.	40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying	46.53	25.77	4.93
	F-test	S	S	S
	SEm+	0.83	1.82	0.15
	CD (P= 0.05)	2.45	5.36	0.43

Table 2: Response of sulphur and iron fertilization on growth parameters of greengram

S.No.	Treatment combinations	Dry weight (g) At 60 DAS	Crop growth rate (g/m^2/day) At 30-45 DAS	Relative growth rate (g/g/day) At 15-30 DAS
1.	Control (No sulphur + No iron)	6.35	5.22	0.072
2.	No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	6.95	5.40	0.075
3.	No sulphur + 25 kg/ha $FeSO_4$ as basal dose application.	7.08	5.38	0.072
4.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS.	8.87	7.04	0.080
5.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application	10.69	10.08	0.082
6.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	8.07	6.67	0.069
7.	40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	8.18	6.62	0.067
8.	40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application.	8.67	6.91	0.079
9.	40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	7.61	6.02	0.073
10.	40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	8.43	6.71	0.076
11.	40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application.	9.05	7.11	.080
12.	40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying	7.36	5.55	0.075
	F-test	S	S	NS
	SEm+	0.49	0.38	0.004
	CD (P= 0.05)	1.44	1.12	-

Table 3: Response of sulphur and iron fertilization on yield attributes of greengram

S.No.	Treatment combinations	Number of pods per plant	Number of seeds per pod	Test weight (g)
1.	Control (No sulphur + No iron)	27.73	9.87	33.40
2.	No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	29.07	10.13	34.43
3.	No sulphur + 25 kg/ha $FeSO_4$ as basal dose application.	29.87	10.27	34.87
4.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS.	34.93	11.73	36.37
5.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application	36.07	12.07	37.03
6.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	32.87	10.93	35.40
7.	40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	33.47	11.13	35.73
8.	40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application.	34.27	11.53	36.57
9.	40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	32.20	10.87	35.27
10.	40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	33.87	11.20	36.40
11.	40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application.	35.93	11.93	36.83
12.	40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying	31.27	10.53	35.07
	F-test	S	S	NS
	SEm±	0.70	0.23	0.10
	CD (P= 0.05)	2.04	0.68	-

Table 4: Response of sulphur and iron fertilization on seed yield, stover yield and harvest index of greengram

S.No.	Treatment combinations	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1.	Control (No sulphur + No iron)	936.67	2493.33	27.30
2.	No sulphur + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	1020.00	2605.00	28.13
3.	No sulphur + 25 kg/ha $FeSO_4$ as basal dose application.	1043.33	2685.00	27.98
4.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS.	1326.67	3176.67	29.45
5.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application	1421.00	3306.00	30.06
6.	20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	1171.67	2916.67	28.06
7.	40 kg/ha Sulphur as single super phosphate + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	1250.00	2956.00	29.72
8.	40 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application.	1311.67	3101.67	29.72
9.	40 kg/ha Sulphur as single super phosphate + No (0) $FeSO_4$ (Distilled water spraying)	1093.33	2875.00	27.55
10.	40 kg/ha Sulphur as gypsum + 0.5% $FeSO_4$ Foliar spray at 25 DAS and 45 DAS	1299.00	3050.13	29.87
11.	40 kg/ha Sulphur as gypsum + 25 kg/ha $FeSO_4$ as basal dose application.	1348.33	3140.00	30.04
12.	40 kg/ha Sulphur as gypsum + No (0) $FeSO_4$ (Distilled water spraying	1061.67	2791.67	27.55
	F-test	S	S	S
	SEm±	37.36	55.51	0.38
	CD (P= 0.05)	109.57	162.79	1.12

Effect of FeSO4

Application of 25 kg/ha $FeSO_4$ as basal dose significantly increased the growth parameters, yield attributes and yield of greengram than foliar spray of 0.5% $FeSO_4$ at 25 DAS and 45 DAS. Maximum yield (1421.00 kg/ha), stover yield (3306.00 kg/ha) and maximum harvest index (30.06), growth parameters and yield attributes *viz.* plant height, number of nodules per plant, number of branches per plant, dry weight, crop relative rate, relative growth rate, number of pods per plant, number of seeds per pods increased significantly in treatment 5 (20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application). Increased availability of iron 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 higher harvest index (Singh *et al.* 1999 and Bera *et al.* 2015) [15, 2].

Conclusion

It is concluded from the experimental finding that the treatment 5 application with 20 kg/ha Sulphur as gypsum + 20 kg/ha Sulphur as single super phosphate + 25 kg/ha $FeSO_4$ as basal dose application was found more productive and can be adopted by the farmers for getting maximum yield and returns from greengram crop as compared to other treatment combinations.

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