

Effect of Iron Sulfate Application on Yield, Nutrient Uptake and Available Nutrient Status of Soybean at Harvest (*Glycine max* L.) in Vertisols of Karnataka, India

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Abstract An experiment was conducted during *kharif* season of 2014-15 in MARS, UAS, Dharwad to know the effect of iron sulfate application on yield, nutrient uptake and available nutrient status at harvest of soybean (*Glycine max* L.) (JS-335) in Vertisols of Northern Karnataka, India. The field experiment was laid-out in RCBD and each treatment was replicated thrice, i.e. soil application of 0, 10, 20 and 30 kg FeSO₄ ha⁻¹ with no spray, one spray at 30 DAS and two sprays at 30 and 45 DAS of 0.5% FeSO₄ to each soil applied treatments. Application of iron sulfate at the rate of 20 kg ha⁻¹ with two iron sulfate (0.5%) sprays at 30 and 45 DAS had significantly increased grain yield (15.29 q ha⁻¹) and straw yield (25.59 q ha⁻¹), nitrogen (176.45 kg ha⁻¹), potassium (61.96 kg ha⁻¹), sulfur (19.41 kg ha⁻¹) and iron uptake (264.27 g

ha⁻¹) which was at par with treatment of 20 kg ha⁻¹ iron sulfate with one spray at 30 DAS. Available iron (3.84 mg kg⁻¹) status in soil at harvest was found superior with treatment receiving iron sulfate at the rate of 30 kg ha⁻¹ with two iron sulfate (0.5%) sprays at 30 and 45 DAS.

Keywords Grain yield, Nutrient uptake, Available nutrients, Iron sulfate, Soybean.

Introduction

Soybean (*Glycine max* (L.) Merrill), a grain legume is considered as a wonder crop due to its dual qualities viz., high protein (40–43%) and oil content (20%). Soybean is being rich source of amino acids, unsaturated fatty acids, vitamins and minerals is being widely used in different forms and acquires special importance in diet of Indian and other Asian countries as a substitute to relieve from hunger and malnutrition. Soybean oil is widely used as edible oil and also as raw material in manufacturing of antibiotics, paints, varnishes, adhesives and lubricants. Hence, soybean finds diverse utilities as oil, protein, medicine and industrial important crop.

Iron is the fourth most abundant element in the earth's crust after oxygen, silicon and aluminium. In India, iron deficiency seems to be one-fourth as extensive as that of Zn, amongst the micronutrients. In Karnataka state, the result reported by research in-

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stitutions and State Department of Agriculture, indicated that 39% of soil samples were found deficient in iron.

In plant, iron plays a role in the synthesis of chlorophyll, carbohydrates production, cell respiration, chemical reduction of nitrates and sulfate and in nitrogen assimilation. Iron deficiency symptoms appear on younger leaves indicating yellowish interveinal areas of leaves commonly referred to as iron chlorosis. In case of severe deficiency, leaves almost pale-white due to loss of chlorophyll.

Cultivation of soybean has been increasing rapidly and now it is the first in area (12.03 million hectares) and second in production (12.23 million tonnes) among oilseed crops grown in the country [1]. Being oilseed and pulse crop, proper nutrient management is one of the crucial factors for getting optimum yield.

Materials and Methods

An experiment was conducted during *kharif* season of 2014–15 in MARS, UAS, Dharwad, located at 15° 26' N latitude and 75°07' E longitude and at an altitude of 678 m above mean sea level under Northern Transitional Zone (Zone 8) of Karnataka to know the effect of iron sulfate application on yield, nutrient uptake and available nutrient status at harvest of soybean (*Glycine max* L.) (JS-335) in *Vertisols* of Northern Karnataka, India. The annual rainfall received during 2014 was 962.20 mm distributed in 69 rainy days. The rainfall during cropping period (July–October) was 604.20 mm. Other parameters namely, maximum and minimum temperature and relative humidity did not have any adverse effect on crop growth and yield. The mean maximum temperature during the period of experimentation ranged from 30°C (October) to 27°C (July and August). The experimental soil was clay in texture with 1.38 Mg m⁻³ bulk density, neutral in reaction (7.81), EC of 0.18 dS m⁻¹, calcareous (5.5%) in nature, medium in organic carbon (0.54%), available nitrogen (340 kg ha⁻¹) and phosphorus (30 kg ha⁻¹) and high in available potassium (365 kg ha⁻¹) and sulfur (21 kg ha⁻¹). Soil was inherently deficient in DTPA-extractable iron (3.41 mg kg⁻¹).

The field experiment was laid-out in RCBD and each treatment was replicated thrice, treatment details are given in Table 1. Iron was applied in the form of iron sulfate (FeSO₄·7H₂O) cured with FYM at 1 : 1 ratio for 15 days before soil application. Recommended package of the practices, i.e. RDF (40 : 80 : 25 kg NPK ha⁻¹) + FYM (6 t ha⁻¹) + soil application of ZnSO₄·7H₂O @ 12 kg ha⁻¹ + seed treatment with *Rhizobium* and PSB @ 1250 g ha⁻¹ seeds were followed along with pest management, irrigation and other practices to raise a healthy crop. Field data were collected on seed and straw yield. Pods were harvested from the net plot area and dried under sun and weighted for seed and straw yield. Physical property of soil like bulk density was measured by core method. Analyzed the chemical properties like available phosphorus (ascorbic acid method), potassium (neutral normal ammonium acetate extractant) and sulfur (turbidometric method) at harvest. CaCO₃, organic carbon (wet oxidation method) available nitrogen (Kjeldhal method) and micronutrient (DTPA extraction followed by AAS estimation) were also analyzed at initial and at harvest of crop. Plant uptake of nutrients were analyzed at harvest of crop.

Results and Discussion

Yield

Application of 20 kg FeSO₄ ha⁻¹ with two iron sulfate sprays at 30 and 45 DAS (T₉) recorded significantly higher seed yield (15.29 q ha⁻¹) and straw yield (25.59 q ha⁻¹) and lowest seed yield of 12.46 q ha⁻¹ and straw yield of 18.42 q ha⁻¹ was recorded in T₁ which received only RPP. However, treatment T₉ was on par with T₈ (20 kg FeSO₄ ha⁻¹ with one iron sulfate spray at 30 DAS) (15 q ha⁻¹), T₁₀, T₁₁ and T₁₂ with respect to seed yield and T₆, T₈ (23.37 q ha⁻¹) and T₁₀ with respect to straw yield. The treatment T₉ was superior over rest of the treatment (Table 2). This might be due to increased iron availability in soil which is inherently deficient in available iron and higher concentration of iron in soybean leaves due to foliar iron application. Thus, the overall effect of iron application benefited in increasing seed and straw yield. The results are collaborate with the findings of Rajamani and Shanmugasundaram [2], who's result revealed that soil application of ferrous sulfate at 50 kg ha⁻¹

Table 1. Treatment details. RPP is common from T₂ to T₁₂. DAS–Days after sowing. NS–Non significant. RPP=RDF + FYM + Soil application of ZnSO₄ 7H₂O@ 12 kg ha⁻¹ + Seed treatment with *Rhizobium* and PSB.

T ₁	RPP
T ₂	FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 DAS
T ₃	FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 and 45 DAS
T ₄	FeSO ₄ .7H ₂ O @ 10 kg ha ⁻¹ (soil)
T ₅	FeSO ₄ .7H ₂ O @ 10 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 DAS
T ₆	FeSO ₄ .7H ₂ O @ 10 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 and 45 DAS
T ₇	FeSO ₄ .7H ₂ O @ 20 kg ha ⁻¹ (soil)
T ₈	FeSO ₄ .7H ₂ O @ 20 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 DAS
T ₉	FeSO ₄ .7H ₂ O @ 20 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 and 45 DAS
T ₁₀	FeSO ₄ .7H ₂ O @ 30 kg ha ⁻¹ (soil)
T ₁₁	FeSO ₄ .7H ₂ O @ 30 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 DAS
T ₁₂	FeSO ₄ .7H ₂ O @ 30 kg ha ⁻¹ (soil) + FeSO ₄ .7H ₂ O (0.5%) foliar spray at 30 and 45 DAS

resulted in higher plant height and yield in all the genotypes of blackgram as compared to control.

Nutrient uptake

Nutrients play a major role in increase growth and ultimately the yield. The data on nutrient uptake of

soybean (N, K and S) differ significantly with the application of iron (Table 2). But P uptake was not significant. Application of iron had significantly increased N, K and S uptake by soybean. The treatment receiving 20 kg FeSO₄ ha⁻¹ with two iron sprays at 30 and 45 DAS registered higher nitrogen (176.45 kg ha⁻¹), potassium (61.96 kg ha⁻¹) and sulfur (19.41

Table 2. Yield, major nutrient uptake by soybean at harvest as influenced by iron application. RPP is common from T₂ to T₁₂. DAS–Days after sowing. NS–Non significant. Values in parentheses indicates per cent nutrient content.

Treatments	Yield (q ha ⁻¹)		Major nutrient uptake (kg ha ⁻¹)					
	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total
T ₁	12.46	18.42	72.15 (5.79)	46.49 (2.52)	118.64	5.29 (0.42)	6.44 (0.35)	11.72
T ₂	12.95	20.02	75.61 (5.83)	52.23 (2.61)	127.84	5.54 (0.43)	7.10 (0.36)	12.64
T ₃	13.21	21.14	80.16 (6.05)	56.92 (2.70)	137.09	5.84 (0.44)	7.64 (0.36)	13.48
T ₄	12.93	19.68	78.03 (6.03)	52.51 (2.66)	130.55	5.57 (0.43)	6.92 (0.35)	12.53
T ₅	13.36	21.65	83.33 (6.21)	58.89 (2.73)	142.23	5.99 (0.45)	7.92 (0.37)	13.91
T ₆	13.56	23.37	85.87 (6.32)	67.44 (2.88)	153.32	6.30 (0.46)	8.64 (0.37)	14.95
T ₇	13.78	22.64	86.08 (6.24)	63.24 (2.79)	149.33	6.20 (0.45)	8.24 (0.36)	14.44
T ₈	15.00	24.25	96.27 (6.14)	70.49 (2.91)	166.77	7.05 (0.47)	9.30 (0.38)	16.36
T ₉	15.29	25.59	100.52 (6.58)	75.92 (2.97)	176.45	7.53 (0.40)	10.06 (0.39)	17.59
T ₁₀	14.82	23.38	92.91 (6.26)	66.63 (2.85)	159.54	6.87 (0.46)	9.04 (0.39)	15.91
T ₁₁	14.53	22.67	89.97 (6.19)	63.45 (2.80)	153.42	6.57 (0.45)	8.30 (0.37)	14.87
T ₁₂	14.25	22.10	87.46 (6.13)	61.51 (2.78)	148.98	6.33 (0.44)	7.67 (0.35)	14.00
SEm±	0.50	0.98	4.07	3.20	5.49	0.65	0.69	9.42
CD (0.05)	1.46	2.88	11.95	9.38	16.11	NS	NS	NS

Table 2. Continued.

Treatments	Major nutrient uptake (kg ha ⁻¹)					
	Grain	Potassium Straw	Total	Grain	Sulfur Straw	Total
T ₁	7.65 (0.62)	29.20 (1.59)	36.86	5.24 (0.42)	6.44 (0.35)	11.67
T ₂	8.29 (0.64)	33.45 (1.66)	41.74	5.82 (0.45)	7.10 (0.36)	12.92
T ₃	8.78 (0.66)	35.81 (1.71)	44.59	6.40 (0.49)	7.70 (0.36)	14.10
T ₄	8.49 (0.66)	32.95 (1.67)	41.44	5.94 (0.46)	7.11 (0.36)	13.05
T ₅	8.98 (0.67)	37.88 (1.75)	46.86	7.11 (0.54)	8.05 (0.37)	15.16
T ₆	9.98 (0.74)	42.76 (1.83)	52.73	7.36 (0.54)	8.89 (0.38)	16.25
T ₇	9.64 (0.70)	40.06 (1.76)	49.70	6.94 (0.50)	8.36 (0.37)	15.30
T ₈	11.54 (0.77)	45.55 (1.88)	57.09	8.35 (0.56)	9.62 (0.40)	17.97
T ₉	12.82 (0.84)	49.14 (1.92)	61.96	8.93 (0.58)	10.48 (0.41)	19.41
T ₁₀	11.16 (0.75)	42.13 (1.80)	53.29	8.27 (0.56)	9.24 (0.40)	17.51
T ₁₁	10.73 (0.74)	39.64 (1.75)	50.37	7.66 (0.53)	8.78 (0.39)	16.44
T ₁₂	10.33 (0.73)	38.13 (1.73)	48.46	7.37 (0.52)	8.47 (0.38)	15.83
SEm±	0.54	2.21	2.00	0.27	0.43	0.60
CD (0.05)	1.60	6.48	5.87	0.78	1.27	1.76

kg ha⁻¹) uptake by soybean crop at harvest which was at par with treatment T₈ (20 kg FeSO₄ ha⁻¹ with one iron sulfate spray at 30 DAS) (166.77 and 57.09 kg ha⁻¹ of N and K respectively) with respect to N and K uptake, T₈ (17.97 kg ha⁻¹) and T₁₀ (17.51 kg ha⁻¹) with respect to S uptake. Lowest of N, K and S uptake of 118.64 kg ha⁻¹, 36.86 kg ha⁻¹ and 11.67 kg ha⁻¹ respectively was recorded in T₁ (RPP). The higher uptake of nitrogen, potassium and sulfur could be due to increased iron availability in soil and the direct

uptake of ferrous iron by the leaves resulting in higher production of chlorophyll, dry matter production, yield and yield components viz., pod number per plant and seed yield per plant of soybean and hence resulted in higher uptake of nitrogen, potassium and sulfur by plants. Results were in accordance with findings of Hemn [3] who's research revealed that application of 2 mg kg⁻¹ of Fe was helped in higher uptake of P, K and increased protein content (N) of cowpea.

Table 3. Micronutrient uptake, available nutrients at harvest of soybean as influenced by iron application. RPP is common from T₂ to T₁₂. DAS–Days after sowing. NS–Non significant. RPP + RDF + FYM + Soil application of ZnSO₄ 7H₂O @ 12 kg ha⁻¹ + Seed treatment with *Rhizobium* and PSB.

Treatments	Micronutrient uptake (g ha ⁻¹)				Available nutrients (kg ha ⁻¹)				Available micronutrients (mg kg ⁻¹)			
	Fe	Mn	Zn	Cu	N	P	K	S	Fe	Mn	Zn	Cu
T ₁	162.61	77.60	56.09	38.23	323.3	29.1	371.1	24.4	3.33	5.35	0.46	0.41
T ₂	178.24	82.73	62.86	40.99	320.0	29.0	369.7	24.3	3.34	5.36	0.46	0.43
T ₃	195.85	86.91	67.20	42.83	316.6	28.6	381.2	24.1	3.35	5.4	0.47	0.44
T ₄	180.38	81.83	61.00	41.17	322.3	28.9	365.5	24.1	3.46	5.38	0.46	0.43
T ₅	202.91	89.32	68.23	43.88	315.6	28.2	364.6	23.9	3.49	5.43	0.47	0.44
T ₆	220.25	94.16	71.34	46.40	308.6	28.1	361.3	23.8	3.53	5.46	0.48	0.45
T ₇	212.58	92.44	68.03	45.91	312.6	28.2	359.6	23.7	3.64	5.41	0.47	0.44
T ₈	243.01	102.63	74.54	49.90	308.6	27.9	357.2	23.6	3.65	5.48	0.49	0.45
T ₉	264.47	107.61	78.67	52.08	306.6	27.7	354.9	23.5	3.67	5.51	0.50	0.47
T ₁₀	221.92	100.38	70.51	48.75	313.3	27.4	361.7	23.7	3.80	5.47	0.46	0.45
T ₁₁	212.46	97.28	65.90	47.45	315.4	27.3	365.7	23.9	3.82	5.45	0.45	0.45
T ₁₂	203.69	94.86	64.61	46.22	318.5	27.0	369.0	24.0	3.84	5.44	0.43	0.44
SEm±	8.36	6.22	4.21	2.83	11.62	1.00	15.58	1.27	0.09	0.23	0.01	0.02
CD (0.05)	24.53	NS	NS	NS	NS	NS	NS	NS	0.28	NS	NS	NS
Initial					340.00	30.0	365.00	21.0	3.41	5.51	0.49	0.46

The data on micronutrient uptake of soybean did (Mn, Cu and Zn) not differ significantly with the application of iron, but Fe uptake was significant (Table 3). Significantly, higher total iron uptake at harvest was recorded in treatment T₉ (264.47 g ha⁻¹) which was at par with T₈ (243.01 g ha⁻¹) followed by T₁₀ (221.92 g ha⁻¹), T₆ (220.25 g ha⁻¹), T₇ (212.58 g ha⁻¹), T₁₁ (212.46 g ha⁻¹), T₁₂ (203.69 g ha⁻¹) and T₅ (202.91 g ha⁻¹) and they were at par with each other. Increase in total iron content in plant at harvest could be due to increased iron availability in an inherently iron deficient soil and the direct uptake of ferrous iron by leaves resulting in higher production of chlorophyll, dry matter and total iron content of plants. The results of present investigation are in accordance with the reports Soheil et al. [4] who revealed that iron application resulted more its concentration in leaf but its further increase (25 kg ha⁻¹) resulted negative effect on soybean.

Available nutrient status

The data on the nutrients status in soil (N, P₂O₅, K₂O, Zn, Mn and Cu) did not differ significantly due to iron application at soybean harvest, whereas, the results on DTPA-extractable iron indicates that levels of applied iron significantly increased the DTPA-extractable iron at harvest of soybean (Table 3). The treatment T₁₂ that received 30 kg FeSO₄ ha⁻¹ with two iron spray at 30 and 45 DAS has recorded the highest DTPA-extractable iron (3.84 mg kg⁻¹) which was at par with T₇ (3.64 mg kg⁻¹), T₈ (3.65 mg kg⁻¹), T₉ (3.67 mg kg⁻¹), T₁₀ (3.80 mg kg⁻¹) and T₁₁ (3.82 mg kg⁻¹). Treatment T₁₂ was superior over rest of the treatments. Lowest iron in soil was recorded in T₁ (3.33 mg kg⁻¹) (RPP). This could be due to more vegetative growth and root growth which releases hydrogen ion,

phenolic compounds and organic acids helped in increased availability and uptake of iron by plants and it might be also due to higher application of iron to the soil. Similar observations were recorded by Ibrahim et al. [5], who reported that application of iron containing amendments like pyrite has increased the iron availability in soil at harvest of the wheat-maize cropping system.

Conclusion

Application of 20 kg FeSO₄ ha⁻¹ with one iron spray at 30 DAS found superior with respect seed, straw yield and nutrient uptake (N, K, S and Fe) by soybean crop. Available iron content in the soil after harvest of the crop was higher in the treatment receiving 30 kg FeSO₄ ha⁻¹ with two iron sprays at 30 and 45 DAS.

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