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Influence of micronutrients on content and uptake of nutrients by soybean (*Glycine max* L.) in inceptisols

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Abstract

The present investigation entitled “Effect of iron and zinc on soil properties, nutrient uptake and yield of soybean (*Glycine max* L.) in Inceptisol” during *Kharif* season of year, 2021-2022 at Research farm Department of Soil Science and Agricultural Chemistry, College of Agriculture, Latur. The experiment was laidout in RBD with three replications and recommended variety of soybean MAUS-158 as a test crop along with nine treatments. Significantly higher uptake of N, P, K, S, Fe and Zn was found in soybean with application of RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄.

Keywords: Nanourea, conventional urea, growth, LAI, yield and wheat.

Introduction

A wonder crop soybean (*Glycine max* L.) is a leguminous crop which belongs to family leguminaceae with sub family papilionaceae. Soybean was introduced in India probably as soon as it was domesticated in China. Soybean is an important crop in human and animal nutrition because it is major source of edible vegetable oil and high protein containing food in the world. It contains about protein (40-42%), carbohydrates (23%) and cholesterol free oil (18-20%). Soybean protein is rich in valuable amino acid lysine (5%) which is deficient in most of the cereals. It also contains 60% polyunsaturated fatty acids (52.8% linolenic acid + 7.2% Linoleic acid). It has high caloric value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereals of same quantity. Soybean is a global crop that is known as golden bean and poor man's meat.

Micronutrient deficiencies in crop plants are widespread because of increased micronutrient demand from intensive cropping practices and adaptation of high-yielding crop cultivars, enhanced crop production on marginal soils that contain low levels of essential micronutrients, increased use of high analysis fertilizers with low amounts of micronutrients, decreased use of animal manures, composts and crop residues, use of soils low in micronutrient reserves, use of liming in acid soils, involvement of natural and anthropogenic factors that limit adequate supplies and create elemental imbalance in soil Fageria *et al.*, (2002) [2]. Shukla and Behera (2011) [12] reported that as much as 48, 12, 5, 4, 33, 13 and 41 per cent soils in India are affected with deficiency of Zn, Fe, Mn, Cu, B, Mo and S, respectively.

Metal such as iron is very important for normal growth of soybean (Fageria *et al.*, 2002) [2]. It also plays an important role in the formation of some nodule proteins like nitrogenase and leghaemoglobin (Moran *et al.*, 1997) [9]. Zinc plays important role in activating the enzymatic systems, zinc is essential for synthesis of chlorophyll and carbohydrates. Zinc is considered as the most limiting factor in producing crop in different parts of the world. Zinc deficiency reduces nutritional value, yield and production of soybean crop. Among the micronutrients, Zn and Fe nutrition can affect the susceptibility of plants to drought.

Micronutrients play many complex roles in plant nutrition and plant production. While, most of the micronutrients participate in the functioning of enzyme systems, there is considerable variation in the specific functions of the various micronutrients in plant and microbial growth processes. For example, copper, iron, and molybdenum are capable of acting as electron carriers in the enzyme systems that brings about oxidation-reduction reaction in plants. Such reactions

are essential in photosynthesis and many other metabolic processes. Zinc and manganese involve in many plant enzyme system as bridges to connect the enzyme with the substrate upon which it is meant to act.

Materials and Methods

Field experiment entitled “Effect of iron and zinc on soil properties, nutrient uptake and yield of soybean (*Glycine max* L.) in Inceptisol” was conducted at Soil Science and Agricultural Chemistry Departmental Research Farm, College of Agriculture, Latur during *kharif* season 2021 on sorghum variety MAUS-158. The topography of experimental field was uniform and leveled. The experimental soil was slightly alkaline in nature. The total geographical area of Latur district is 7.37 mha. Geographically Latur district comes under Maharashtra state which is located between 18° 05' to 18° 75' North. The soils of Latur district belongs to order Vertisols, Inceptisol and Entisol derived from Deccan trap. RDF (30:60:30:20 kg NPKS ha⁻¹) supplied through Urea, SSP, MOP & Bensulf.

The experimental soil was clayey in texture, calcareous in nature, moderately alkaline reaction, low in content of organic carbon (5.60 g kg⁻¹), available nitrogen (216.12 kg ha⁻¹), available phosphorous (18.24 kg ha⁻¹), high in available potassium (453.15 kg ha⁻¹), available sulphur (27.55 kg ha⁻¹), DTPA zinc (1.14 kg ha⁻¹) and DTPA iron (7.7 kg ha⁻¹). The experiment was laid out in randomized block design with nine treatments and three replications, respectively.

Results and Discussion

1. Effect of iron and zinc on Nitrogen content and uptake by soybean

The data on content and uptake of N as influenced by application of iron and zinc after harvesting of soybean crop are presented in table 1. The N concentration in soybean seed and straw varied between 5.49 to 5.76 per cent and 0.22 to 0.40 per cent, respectively. The highest N concentration in seed (5.76%) and straw (0.40%) of soybean was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (5.72% in seed) and (0.39% in straw) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (5.72% in seed) and (0.39% in straw). Whereas the minimum concentration of N in seed (5.49%) and straw (0.22%), respectively observed in treatment T₁ (RDF).

The uptake of nitrogen in soybean seed and straw ranged from

103.78 kg ha⁻¹ to 131.50 kg ha⁻¹, respectively. The highest N uptake in soybean seed (131.50 kg ha⁻¹) and straw (15.73 kg ha⁻¹) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (129.38 kg ha⁻¹ in seed) and (14.98 kg ha⁻¹ in straw) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (127.88 kg ha⁻¹ in seed) and (14.81 kg ha⁻¹ in straw). Whereas the minimum uptake of N in seed (103.78 kg ha⁻¹) and in straw (6.78 kg ha⁻¹), respectively observed in treatment T₁ (RDF).

Similar trend was observed in total nitrogen uptake of soybean. Maximum total N uptake (147.23 kg ha⁻¹) was recorded in treatment receiving T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (144.36 kg ha⁻¹) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (142.69 kg ha⁻¹). Whereas the lowest total uptake of N (110.57 kg ha⁻¹) recorded in treatment T₁ (RDF).

Pable *et al.* (2011) [10] also revealed similar result with application of 30 kg S ha⁻¹ and 2.5 kg Zn ha⁻¹ with fertilizer dose 30:75:0 NPK ha⁻¹ and recorded significant effect on uptake of nitrogen (213.39 kg ha⁻¹).

Pable *et al.* (2011) [10] also revealed similar result with application of 30 kg S ha⁻¹ and 2.5 kg Zn ha⁻¹ with fertilizer dose 30:75:0 NPK ha⁻¹ and recorded significant effect on uptake of nitrogen (213.39 kg ha⁻¹). The increase nitrogen uptake might be due to sulphure and zinc which helps to increases nitrogen fixation, root growth and promote nodule formation in root of leguminous crop.

Similarly, Kumar *et al.* (2014) [5] found that application 100% NPK+ Zn 25 kg ha⁻¹ + Fe @ 25 kg ha⁻¹ to mustard recorded highest uptake of nitrogen (97.87 kg ha⁻¹) by grains. The increases nitrogen uptake in mustard crop might be due to the favourable influence of zinc on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plants parts including seed, which ultimately increased the uptake of N in seed.

Laharia *et al.* (2015) [6] reported that application of @ 125% RDP+ 5 kg Zn ha⁻¹ in soybean recorded highest nitrogen content in grain (6.46%), straw (0.89%) and highest total uptake of nitrogen (62.10 kg ha⁻¹). The increase N content and uptake may be due to zinc play an important role in synthesis of DNA and RNA and mobilizing carbohydrate, lipid and protein production.

Table 1: Effect of iron and zinc on nitrogen content (%) and nitrogen uptake (kg ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	5.49	103.78	0.22	6.78	110.57
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	5.60	122.45	0.39	14.12	136.56
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	5.64	116.43	0.37	12.81	129.24
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	5.72	127.88	0.38	14.98	142.85
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	5.61	115.19	0.37	12.67	127.86
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	5.62	121.53	0.39	14.06	135.59
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	5.76	131.50	0.37	14.81	146.32
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	5.61	122.89	0.36	13.49	136.38
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	5.72	129.38	0.40	15.73	145.10
SE±	0.07	1.79	0.009	0.35	1.86
CD at 5%	NS	5.39	0.02	1.07	5.59

2. Effect of iron and zinc application on Phosphorus content and uptake by soybean

The data on content and uptake of P as influenced by application

of iron and zinc after harvest of soybean crop are presented in table 2. The phosphorus concentration in soybean seed and straw varied between 0.42 to 0.35 per cent and 0.14 to 0.12 per cent,

respectively. The highest P concentration in seed (0.42%) and straw (0.14%) of soybean was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (0.41% in seed) and (0.14% in straw) and T₆ (RDF + 25 kg ha⁻¹ ZnSO₄) (0.41% in seed) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (0.14% in straw). Whereas the lowest concentration of P in seed (0.35%) and straw (0.12%), respectively observed in treatment T₁ (RDF).

The uptake of phosphorus in soybean seed and straw ranged from 6.61 kg ha⁻¹ to 9.58 kg ha⁻¹ and 3.59 kg ha⁻¹ to 5.66 kg ha⁻¹, respectively. The highest P uptake in soybean seed (9.58 kg ha⁻¹) and straw (5.66 kg ha⁻¹) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (9.34 kg ha⁻¹ in seed) and (5.62 kg ha⁻¹ in straw), T₄ (RDF + 0.5% each Foliar spray of FeSO₄ + ZnSO₄ at 30 and 45 DAS) (8.52 kg ha⁻¹ in seed) and (5.47 kg ha⁻¹ in straw), T₆ (RDF + 25 kg ha⁻¹ ZnSO₄) (8.86 kg ha⁻¹ in seed), T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (5.47 kg ha⁻¹ in straw) and T₈ (RDF+ Grade I micronutrients formulation @ 25 kg ha⁻¹) (5.00 kg ha⁻¹ in straw). Whereas the minimum uptake of P in seed (6.61 kg ha⁻¹) and in straw (3.59 kg ha⁻¹), respectively observed in treatment T₁ (RDF).

Similar trend was observed in case of total phosphorus uptake of soybean. Highest total uptake of soybean (15.24 kg ha⁻¹) was found in treatment receiving T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (14.97 kg ha⁻¹) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (13.75 kg ha⁻¹). Whereas the lowest total uptake of N (10.19 kg ha⁻¹) observed in treatment T₁ (RDF).

Pable *et al.* (2011) [10] similarly revealed that application of 30 kg S ha⁻¹ and 2.5 kg Zn ha⁻¹ with fertilizer dose 30:75:0 NPK ha⁻¹ recorded significant effect on uptake of phosphorus (36.38 kg ha⁻¹). The result might be due to improve in plant growth and carbohydrate metabolism and zinc increased the absorption of phosphorus from roots to above ground part due to formation of Zn₃(PO₄)₂ compounds.

Kumar *et al.* (2014) [5] concluded that application 100% NPK+ Zn 25 kg ha⁻¹ + Fe @ 25 kg ha⁻¹ to mustard recorded highest uptake of phosphorus (21.82 kg ha⁻¹) by grains. Zinc play important role in biosynthesis of IAA which lead to portioning of photosynthates toward vegetative part of plant thus ultimately responsible for movement of nutrient in plant.

Laharia *et al.* (2015) [6] reported that application of @ 125% RDP+ 5 kg Zn ha⁻¹ in soybean recorded highest phosphorus content in grain (0.44%) and straw (0.24%). and also highest uptake of Phosphorus (5.94 kg ha⁻¹).

Table 2: Effect of iron and zinc on phosphorus content (%) and phosphorus uptake (kg ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	0.35	6.61	0.12	3.59	10.19
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	0.39	8.27	0.13	4.94	13.47
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	0.37	7.65	0.13	4.51	12.16
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	0.37	8.52	0.14	5.47	13.74
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	0.38	7.80	0.13	4.41	12.21
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	0.41	8.86	0.12	4.57	13.43
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	0.42	9.58	0.14	5.66	15.24
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	0.37	8.16	0.13	5.00	13.16
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	0.41	9.34	0.14	5.62	14.97
SE±	0.016	0.37	0.007	0.29	0.50
CD at 5%	NS	1.13	NS	0.88	1.49

Elayaraja and Singaravel (2016) [1] concluded that application 150% NPK + Zn @30 kg ha⁻¹ + B @15 kg ha⁻¹ in groundnut recorded highest phosphorus uptake by pod (11.89 kg ha⁻¹), by haulm (14.23 kg ha⁻¹). The higher P uptake may be due to solubilization of native P by organic acids in addition to applied fertilizers which ultimately resulted in better root growth and increased physiological activity of roots to absorb more P.

3. Potassium content and uptake by soybean

The data on content and uptake of K as influenced by application of iron and zinc after harvest of soybean crop are presented in table 3. The potassium concentration in soybean seed and straw varied between 1.34 to 1.41 per cent and 0.50 to 0.72 per cent, respectively.

The highest K concentration in seed (1.41%) of soybean was recorded with treatment T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) followed by treatments T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) (1.40%) and T₆ (RDF + 25 kg ha⁻¹ ZnSO₄) (1.39%) and in case of straw

concentration (0.72%) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatment T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (0.70%) and T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (0.69%). Whereas the minimum concentration of S observed in seed (1.34%) and straw (0.50%) in treatment T₁ (RDF).

The uptake of potassium in soybean seed and straw ranged from 25.39 kg ha⁻¹ to 31.93 kg ha⁻¹ and 15.03 kg ha⁻¹ to 28.56 kg ha⁻¹, respectively. The highest K uptake in soybean seed (31.93 kg ha⁻¹) and straw (28.56 kg ha⁻¹) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (30.97 kg ha⁻¹ in seed) and (27.38 kg ha⁻¹ in straw) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (31.52 kg ha⁻¹ in seed) and (27.35 kg ha⁻¹ in straw). Whereas the minimum uptake of K in seed (25.39 kg ha⁻¹) and in straw (15.03 kg ha⁻¹), respectively observed in treatment T₁ (RDF).

Table 3: Effect of iron and zinc on potassium content (%) and potassium uptake (kg ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	1.34	25.39	0.50	15.03	40.42
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	1.37	30.07	0.64	23.19	53.26
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	1.37	28.24	0.68	23.58	51.82
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	1.41	31.52	0.70	27.35	58.87
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	1.38	28.30	0.67	22.75	51.05
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	1.39	30.04	0.66	23.79	53.84
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	1.40	31.93	0.72	28.56	60.49
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	1.34	29.34	0.65	24.35	53.69
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	1.37	30.97	0.69	27.38	58.35
SE±	0.015	0.48	0.01	0.45	0.72
CD at 5%	NS	1.46	0.03	1.37	2.16

Similar trend was observed in case of total potassium uptake of soybean. Maximum total potassium uptake (60.49 kg ha⁻¹) was found in treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (58.87 kg ha⁻¹) and T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (58.35 kg ha⁻¹). Whereas the lowest total uptake of K (40.42 kg ha⁻¹) observed in treatment T₁ (RDF).

Pable *et al.* (2011) [10] found that application of 30 kg S ha⁻¹ and 2.5 kg Zn ha⁻¹ with fertilizer dose 30:75:0 NPK ha⁻¹ recorded significant effect on uptake of potassium (76.28 kg ha⁻¹). Increased uptake of potassium may be due to its most availability in soil which related to the plant.

Kumar *et al.* (2014) [5] concluded that application 100% NPK+ Zn 25 kg ha⁻¹ + Fe @ 25 kg ha⁻¹ to mustard recorded highest uptake of potassium (152.82 kg ha⁻¹) by grains.

Elayaraja and Singaravel (2016) [1] concluded that application

150% NPK + Zn @30 kg ha⁻¹ + B @15 kg ha⁻¹ in groundnut recorded highest potassium uptake by pod (36.83 kg ha⁻¹) and by haulm (73.65 kg ha⁻¹). Increased K uptake might be due to better plant growth leading to higher uptake of nutrients and further on the stimulatory effect of B and Zn in absorption of K.

4. Sulphur content and uptake by soybean

The data on content and uptake of S as influenced by application of iron and zinc after harvest of soybean crop are presented in table 4. The sulphur concentration in soybean seed and straw varied between 0.22 to 0.33 per cent and 0.12 to 0.32 per cent, respectively. The highest K concentration in seed (0.33%) and straw (0.32%) of soybean was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) and treatment T₃ (RDF + 0.5% Foliar spray of ZnSO₄ at 30 and 45 DAS), respectively which followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (0.32% in seed) and (0.28% in straw).

Table 4: Effect of iron and zinc on sulphur content (%) and sulphur uptake (kg ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	0.22	4.16	0.12	3.78	7.94
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	0.30	6.70	0.24	8.68	15.38
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	0.28	5.77	0.32	11.08	16.85
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	0.32	7.15	0.26	10.16	17.31
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	0.26	5.33	0.31	10.53	15.86
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	0.29	6.27	0.26	9.38	15.66
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	0.33	7.52	0.32	12.69	20.22
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	0.27	5.92	0.30	11.23	17.15
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	0.32	7.23	0.28	11.01	18.24
SE±	0.013	0.30	0.013	0.48	0.57
CD at 5%	0.039	0.90	0.040	1.46	1.72

Whereas the minimum concentration of S observed in seed (0.22%) and straw (0.12%) in treatment T₁ (RDF).

The uptake of sulphur in soybean seed and straw ranged from 4.16 kg ha⁻¹ to 7.52 kg ha⁻¹ and 3.78 kg ha⁻¹ to 11.90 kg ha⁻¹, respectively. The highest S uptake in soybean seed (7.52 kg ha⁻¹) and straw (11.90 kg ha⁻¹) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (7.23 kg ha⁻¹ in seed) and (11.01 kg ha⁻¹ in straw), T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (7.15 kg ha⁻¹ in seed) and (27.35 kg ha⁻¹ in straw) and T₃ (RDF + 0.5% Foliar spray of ZnSO₄ at 30 and 45 DAS) in seed (5.77) and in straw (11.08 kg ha⁻¹). Whereas the minimum uptake of S in seed (4.16 kg ha⁻¹) and in straw (3.78 kg ha⁻¹) respectively observed in treatment T₁ (RDF). Similar trend was observed in case of total sulphur uptake of soybean. Maximum total sulphur uptake of soybean (19.42 kg ha⁻¹) was observed in treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ +

25 kg ha⁻¹ ZnSO₄) followed by treatment T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (18.24 kg ha⁻¹). Whereas the lowest total uptake of S (7.94 kg ha⁻¹) observed in treatment T₁ (RDF).

Similar results found with application of 30 kg ZnSO₄ ha⁻¹ in soybean recorded highest uptake of sulphur (11.84 kg ha⁻¹). It is well known that uptake of nutrients by a crop is associated with the crop vigour and productivity (Singh *et al.* (2017)) [13]. Roy and Ghosh (2020) [11] found that the application of RDF + Zn @2.5 kg ha⁻¹ + S @40 kg ha⁻¹ in safflower recorded total uptake of sulphur (16.24 kg ha⁻¹).

5. Iron content and uptake by soybean

The data on content and uptake of Fe as influenced by application of iron and zinc after harvest of soybean crop are presented in table 5. The iron concentration in soybean seed and

straw varied between 0.03 to 0.10 per cent and 0.03 to 0.07 per cent, respectively. The highest Fe concentration in seed (0.10%) and straw (0.07%) of soybean was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (0.09% in seed) and (0.06%). Whereas the minimum concentration of Fe observed in seed (0.03%) and straw (0.03%) in treatment T₁ (RDF).

The uptake of iron in soybean seed and straw ranged from 0.63 kg ha⁻¹ to 2.28 kg ha⁻¹ and 0.88 kg ha⁻¹ to 2.77 kg ha⁻¹,

respectively. The highest Fe uptake in soybean seed (2.28 kg ha⁻¹) and straw (2.77 kg ha⁻¹) was recorded with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (2.034 kg ha⁻¹ in seed) and (2.36 kg ha⁻¹ in straw) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (2.23 kg ha⁻¹ in seed) and (1.56 kg ha⁻¹ in straw), Whereas the minimum uptake of Fe in seed (0.63 kg ha⁻¹) and in straw (0.88 kg ha⁻¹) respectively observed in treatment T₁ (RDF).

Table 5: Effect of iron and zinc on iron content (%) and iron uptake (g ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	0.03	0.63	0.03	0.88	1.52
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	0.07	1.60	0.04	1.45	3.05
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	0.05	1.14	0.03	1.03	2.17
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	0.10	2.23	0.04	1.56	3.80
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	0.07	1.44	0.06	2.04	3.47
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	0.05	1.07	0.05	1.80	2.87
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	0.12	2.73	0.09	3.70	6.43
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	0.08	1.76	0.05	1.88	3.64
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	0.10	2.34	0.06	2.36	4.70
SE±	0.014	0.28	0.010	0.36	0.55
CD at 5%	0.042	0.86	0.031	1.10	1.67

Similar trend was observed in case of total iron uptake of soybean. Maximum total uptake of soybean (5.05 kg ha⁻¹) was observed with treatment T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) followed by treatments T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (4.39 kg ha⁻¹) and T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (3.80 kg ha⁻¹). Whereas the lowest total uptake of Fe (1.52 kg ha⁻¹) observed in treatment T₁ (RDF).

Goiba and Durgude (2016) revealed that application of GRDF + 5 t ha⁻¹ FYM + Seed priming with FeSO₄.7H₂O @0.02% recorded highest total uptake of iron (5330 g ha⁻¹). This increase in micronutrient might be due to supply from nutrient imbibed at the time of seed soaking.

Meena *et al.* (2018) [7] reported that application of ZnSO₄ @5.0 kg ha⁻¹ + FeSO₄ @ 7.5 kg ha⁻¹ + FYM @10 t ha⁻¹ in mustard recorded highest total Fe content (63.1 mg kg⁻¹).

Meshram *et al.* (2019) [8] noted that treatment (T₅) 100% NPK + Zn in soybean recorded at par with treatment (T₈) 100% NPK + FYM in case of uptake of nutrients by soybean i.e. uptake of Fe (917.21 g ha⁻¹).

6. Zinc content and uptake by soybean

The data on content and uptake of Zn as influenced by application of zinc and zinc after harvest of soybean crop are presented in table 6. The zinc concentration in soybean seed and

straw varied between 0.60 to 0.76 per cent and 0.63 to 0.77 per cent, respectively. The highest Zn concentration in seed (0.76%) and straw (0.77%) of soybean was recorded with treatment T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) which followed by treatments T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) (0.71% in seed) and (0.77% in straw), T₃ (RDF + 0.5% Foliar spray of ZnSO₄ at 30 and 45 DAS) (0.74% in seed) and (0.77%) and T₆ (RDF + 25 kg ha⁻¹ ZnSO₄) (0.71 in seed) and (0.74 in straw). Whereas the minimum concentration of Zn observed (0.60% in seed) and (0.63% in straw) with treatment T₁ (RDF).

The uptake of zinc in soybean seed and straw ranged from 11.35 kg ha⁻¹ to 16.99 kg ha⁻¹ and 18.92 kg ha⁻¹ to 30.68 kg ha⁻¹, respectively. The highest Zn uptake in seed (16.99 kg ha⁻¹) and straw (30.68 kg ha⁻¹) of soybean was recorded with treatment T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) and T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) respectively which followed by treatments T₇ (RDF + 25 kg ha⁻¹ FeSO₄ + 25 kg ha⁻¹ ZnSO₄) (16.19 kg ha⁻¹ in seed), T₄ (RDF + 0.5% each Foliar spray of FeSO₄ and ZnSO₄ at 30 and 45 DAS) (30.21 kg ha⁻¹ in straw) and T₉ (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (15.90 kg ha⁻¹ in seed) and (29.34 kg ha⁻¹ in straw). Whereas the minimum uptake of Zn in seed (11.35 kg ha⁻¹) and in straw (18.92 kg ha⁻¹) respectively observed in treatment T₁ (RDF).

Table 6: Effect of iron and zinc on zinc content (%) and zinc uptake (g ha⁻¹) in seed, straw and total uptake of soybean after harvest

Treatments	Seed		Straw		Total Uptake
	Content	Uptake	Content	Uptake	
T ₁ : RDF (30 kg N:60 kg P ₂ O ₅ :30 kg K ₂ O:20 kg S ha ⁻¹)	0.60	11.35	0.63	18.92	30.28
T ₂ :RDF + 0.5% Foliar spray of FeSO ₄ at 30 and 45 DAS	0.65	14.33	0.68	24.85	39.18
T ₃ :RDF + 0.5% Foliar spray of ZnSO ₄ at 30 and 45 DAS	0.74	15.37	0.77	26.90	42.27
T ₄ :RDF + 0.5% each Foliar spray of FeSO ₄ and ZnSO ₄ at 30 and 45 DAS	0.76	16.99	0.77	30.21	47.20
T ₅ :RDF + 25 kg ha ⁻¹ FeSO ₄	0.64	13.12	0.65	22.30	35.43
T ₆ :RDF + 25 kg ha ⁻¹ ZnSO ₄	0.71	15.47	0.74	26.84	42.32
T ₇ :RDF + 25 kg ha ⁻¹ FeSO ₄ + 25 kg ha ⁻¹ ZnSO ₄	0.74	17.03	0.77	30.68	47.71
T ₈ :RDF+ Grade I micronutrients formulation @ 25 kg ha ⁻¹	0.68	15.05	0.63	23.83	38.88
T ₉ :RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS	0.70	15.90	0.74	29.34	45.24
SE±	0.033	0.68	0.029	1.06	1.02
CD at 5%	0.100	2.04	0.087	3.18	3.06

Similar trend was observed in case of total zinc uptake of soybean. Maximum total zinc uptake of soybean was (47.20 kg ha^{-1}) was observed in treatment receiving T_4 (RDF + 0.5% each Foliar spray of FeSO_4 and ZnSO_4 at 30 and 45 DAS) followed by treatments T_7 (RDF + $25 \text{ kg ha}^{-1} \text{ FeSO}_4$ + $25 \text{ kg ha}^{-1} \text{ ZnSO}_4$) (46.87 kg ha^{-1}) and T_9 (RDF+ Grade II micronutrients formulation @ 0.5% Foliar spray at 30 and 45 DAS) (45.24 kg ha^{-1}). Whereas the lowest total uptake of Zn (30.28 kg ha^{-1}) observed in treatment T_1 (RDF).

Kour *et al.* (2017)^[4] also reported similar result with application of RDF + 10 kg ZnSO_4 + 2 kg B ha^{-1} in mustard recorded highest uptake of zinc by seed (157.9 g ha^{-1}), by stover (418.7 g ha^{-1}).

Conclusion

Significantly higher content and uptake of N, P, K, S, Fe and Zn by soybean found highest with application of RDF + $25 \text{ kg ha}^{-1} \text{ FeSO}_4$ + $25 \text{ kg ha}^{-1} \text{ ZnSO}_4$ in soybean crop.

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