



# Effect of Micronutrient Application on Content and Uptake of Nutrients and Available Nutrient Status at Harvest of Green Gram Growing Iron and Zinc Deficient Soils of Renapur Tahsil, Latur

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

The present investigation entitled "Effect of micronutrient application in green gram growing iron and zinc deficient soils of Renapur Tahsil, Latur" during *Kharif* season of the year, 2022-2023 at A Field experiment was conducted at farmers field At. Post-Dawangaon Tq-Renapur Dist- Latur. The experiment was layout in RBD with three replications and a recommended variety of green gram BM 2003-2 as a test crop along with ten treatments. Significantly higher uptake of N, P, K, Fe and Zn was found in green gram with treatment T<sub>7</sub> (application of RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub>). Available soil nutrient status in post-soil samples after harvest was comparably found maximum than initial soil samples.

**Keywords:** Green gram; FeSO<sub>4</sub>; ZnSO<sub>4</sub>; RBD; soil nutrient.

## 1. INTRODUCTION

"Green gram (*Vigna radiata* L.) is a well-known domesticated legume crop grown widely all over the world providing an important economy for marginal farmers in the developing countries and a high-value commodity crop with high nutritional quality in the developed nations. Green gram comes under the family *Fabaceae*, subfamily *Papilionaceae*, genus *Vigna* and species *radiata*. This family is widespread as it occupies the third largest family of flowering plants with approximately 650 genera and nearly 20,000 species" (Doyle, 1994). "Green gram is alternatively known as golden gram, mungbean, moong bean, haricot mungo, mash bean, etc. It is an annual, semi-erect to erect or sometimes twining, up to 100 cm tall, deep-rooted herbaceous plant. In India, green gram is mostly grown in Andhra Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Punjab, Uttar Pradesh, etc. India ranks first in both area and production of all important pulses grown in the world. Pulses are grown on about 30.4 million ha. area in India with production of 14.77 million tonnes and productivity pulses is 617 kg ha<sup>-1</sup>. The total area under pulses in Maharashtra is 32.69 lakh ha, with a total production of 21.44 lakh tones and productivity of 217 kg ha<sup>-1</sup>. Green gram ranks third among all the pulses in India after chickpea and pigeon pea. India accounts for almost 65 percent area and 54 percent production of world mung bean. Green gram grown on about 3.57 million ha. Area in India with a total production of 17.89 metric tonnes and productivity of green gram is 500 kg ha<sup>-1</sup>" (Anonymous, 2021).

"Micronutrient deficiencies in soil and 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" (Barkha et al., 2020). Boradkar et al. (2023) reported that "as much as 48, 12, 5, 4, 33, 13, and 41 percent of soils in India are affected by deficiency of Zn, Fe, Mn, Cu, B, Mo, and S, respectively. In general, farmers applied only major nutrients and not the micronutrients are lacking. Micronutrients like Iron, Zinc, Manganese, Copper, Molybdenum, and Boron play an important role in increasing legume yield through their effect on the plant itself, nitrogen-fixing symbiotic process and effective use of major and secondary nutrients. However, they are used in lower amounts as compared to macronutrients. They have a major role in cell division, development of meristematic tissues, photosynthesis, respiration, and acceleration of plant maturity. Nowadays micronutrient deficiencies are found limiting factors for crop growth and optimum yield. Hence, optimum yield potential attained through nutrient management including micronutrient iron and zinc is a basic requirement for major crops and mung bean".

## 2. MATERIALS AND METHODS

A field experiment was conducted at the farmer's field of Shri. Prabhakar Ramrao Nagargoje, At/Post-Dawangaon Tq-Renapur Dist- Latur, during *Kharif*, 2022-2023, college of Agriculture, Latur, Maharashtra. It lies between 76°30'31" E Longitude and 18°35'26" N Latitude. With ten treatments and three replications in randomized block design. T<sub>1</sub>: RDF, T<sub>2</sub>: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha<sup>-1</sup>. T<sub>3</sub>: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS. T<sub>4</sub>: RDF + S.A. Grade-I micro-nutrient @ 25

kg ha<sup>-1</sup> + F.A. Grade-II micro-nutrient 0.5 % at 25 and 40 DAS. T<sub>5</sub>: RDF + S.A. FeSO<sub>4</sub> @ 25 kg ha<sup>-1</sup>. T<sub>6</sub>: RDF + S.A. ZnSO<sub>4</sub> @ 25kg ha<sup>-1</sup>. T<sub>7</sub>: RDF + S.A. FeSO<sub>4</sub> + ZnSO<sub>4</sub> @ 25kg ha<sup>-1</sup>. T<sub>8</sub>: RDF + F.A. FeSO<sub>4</sub> @ 0.5 % at 25 to 40 DAS. T<sub>9</sub>: RDF + F.A. of ZnSO<sub>4</sub> @ 0.5 % at 25 to 40 DAS. T<sub>10</sub>: RDF + F.A. FeSO<sub>4</sub> + ZnSO<sub>4</sub> @ 0.5 % at 25 to 40 DAS. *i. e.* Recommended Dose of Fertilizers N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O (25:50:25 kg ha<sup>-1</sup>) + FYM were applied to green gram. The experimental soil was deep, black in colour, and good drainage, clayey in texture, highly calcareous in nature (18.45 %), moderately alkaline reaction (8.38 pH), and low in content of organic carbon (2.41 g kg<sup>-1</sup>), available nitrogen (165.55 kg ha<sup>-1</sup>), available phosphorous (17.13 kg ha<sup>-1</sup>), high in available potassium (435.45 kg ha<sup>-1</sup>), deficient in DTPA iron (2.16 mg kg<sup>-1</sup>), zinc (0.48 mg kg<sup>-1</sup>) sufficient in DTPA copper and manganese. Soil sample was collected after harvesting of green gram and analysed as per standard methods. The data on various parameters recorded during the period of investigation were tabulated and statistically analysed (Panse & Sukhatme, 1996).

### 3. RESULTS AND DISCUSSION

The data related to the content and uptake of nitrogen, phosphorus, potassium, iron and zinc as influenced by the application of micronutrient with certain treatments.

#### 3.1 Nitrogen Content and Uptake by Green Gram

The data on the content and uptake of N as influenced by the application of micronutrients after harvest of green gram, are presented in Table 1 N concentration in green gram at harvest stage was not significantly influenced by micronutrient fertilization. The highest N concentration (3.58 % in seed and 1.79% in straw) was observed with the application of RDF + Soil application FeSO<sub>4</sub> + ZnSO<sub>4</sub> @ 25kg/ha<sup>-1</sup> (T<sub>7</sub>) respectively and lowest with T<sub>1</sub> (RDF) respectively. The highest uptake of N was observed in green gram seed 55.56 kg ha<sup>-1</sup> and

in straw 33.38 kg ha<sup>-1</sup> was recorded in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum uptake of N in seed (34.88 kg ha<sup>-1</sup>) and in straw (20.48 kg ha<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF).

Total nitrogen uptake of green gram (88.94 kg ha<sup>-1</sup>) was found maximum in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) respectively and was found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and found superior over rest of the treatments. Whereas, the minimum total uptake of N (55.36 kg ha<sup>-1</sup>) was recorded in treatment T<sub>1</sub> (RDF) in green gram. This might be due to the increase in N uptake could be attributed to enhanced vigor of crop growth with increased utilization and translocation of N into plants and synergistic effect between N and Zn in soil system resulting in the enhancement of yield. Similar findings were reported by Lokhande (2018) in green gram and Mane et al. (2021) in pigeon pea.

#### 3.2 Phosphorus Content and Uptake by Green Gram

The data on the content and uptake of P as influenced by the application of micronutrients after the harvest of green grams are presented in Table 2.

Phosphorus concentration in green gram at harvest stage was not significantly influenced by micronutrient fertilization. The highest P concentration (0.45 % in seed and 0.41 % in straw) was observed with the application of (RDF + Soil application FeSO<sub>4</sub> + ZnSO<sub>4</sub> @ 25kg/ha<sup>-1</sup>) T<sub>7</sub> and lowest with T<sub>1</sub> (RDF) (0.38 % in seed and 0.34 % in straw) respectively. The P concentration increased at both stages of green gram due to imposed treatments. At the harvest stage the phosphorus concentration in seed was higher as compared to that of straw.

**Table 1. Effect of micronutrient application on nitrogen content, nitrogen uptake in seed and straw and total uptake of green gram after harvest**

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (%)	Uptake (kg ha <sup>-1</sup> )	Content (%)	Uptake (kg ha <sup>-1</sup> )	
T <sub>1</sub>	3.42	34.88	1.65	20.48	55.36
T <sub>2</sub>	3.52	48.73	1.76	32.04	80.78
T <sub>3</sub>	3.49	38.18	1.75	24.57	62.75
T <sub>4</sub>	3.58	50.45	1.76	32.26	82.71

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (%)	Uptake (kg ha <sup>-1</sup> )	Content (%)	Uptake (kg ha <sup>-1</sup> )	
T <sub>5</sub>	3.56	44.03	1.75	29.06	73.09
T <sub>6</sub>	3.55	42.05	1.72	27.53	69.58
T <sub>7</sub>	3.58	55.56	1.79	33.38	88.94
T <sub>8</sub>	3.44	35.78	1.72	23.01	58.79
T <sub>9</sub>	3.45	35.68	1.71	23.67	59.35
T <sub>10</sub>	3.47	36.89	1.73	23.55	60.44
SE (m) ±	<b>0.04</b>	<b>3.64</b>	<b>0.02</b>	<b>1.52</b>	<b>4.26</b>
CD at 5%	<b>NS</b>	<b>10.82</b>	<b>NS</b>	<b>4.53</b>	<b>12.68</b>

**Table 2. Effect of micronutrient application on phosphorus content, phosphorus uptake in seed and straw and total uptake of green gram after harvest**

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (%)	Uptake (kg ha <sup>-1</sup> )	Content (%)	Uptake (kg ha <sup>-1</sup> )	
T <sub>1</sub>	0.38	3.91	0.34	4.25	8.16
T <sub>2</sub>	0.44	5.93	0.39	7.16	13.08
T <sub>3</sub>	0.39	4.24	0.37	5.16	9.39
T <sub>4</sub>	0.44	6.20	0.41	7.56	13.76
T <sub>5</sub>	0.42	5.23	0.36	6.05	11.28
T <sub>6</sub>	0.41	4.88	0.35	5.63	10.51
T <sub>7</sub>	0.45	7.09	0.41	7.71	14.80
T <sub>8</sub>	0.41	4.31	0.39	5.18	9.49
T <sub>9</sub>	0.40	4.16	0.37	5.16	9.32
T <sub>10</sub>	0.42	4.47	0.40	5.42	9.89
SE (m) ±	<b>0.02</b>	<b>0.41</b>	<b>0.01</b>	<b>0.39</b>	<b>0.58</b>
CD at 5%	<b>NS</b>	<b>1.22</b>	<b>NS</b>	<b>1.17</b>	<b>1.72</b>

The highest uptake of P was observed in green gram seed (7.09 kg ha<sup>-1</sup>) and straw (7.71 kg ha<sup>-1</sup>) was recorded in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and was found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum uptake of P in seed (3.91 kg ha<sup>-1</sup>) and in straw (4.25 kg ha<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF).

Total phosphorus uptake of green gram (14.80 kg ha<sup>-1</sup>) was found maximum with treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum total uptake of P (8.16 kg ha<sup>-1</sup>) was recorded in treatment T<sub>1</sub> (RDF).

Though the phosphorus concentration was non significantly influenced by zinc and iron fertilization but significant increase in phosphorus uptake might be due to the maximum production of dry matter. These results are in close agreement with those reported by Ranpariya et al. (2017) in crops mung bean, Lokhande et al.

(2018) in green gram crop and Mane et al. (2021) in pigeon pea crop.

### 3.3 Potassium Content and Uptake by Green Gram

The data on the content and uptake of K as influenced by the application of micronutrients after the harvest of green grams are presented in Table 3 Potassium concentration in green gram at the harvest stage was not significantly influenced by micronutrient fertilization. The highest K concentration (2.41 % in seed and 1.43 % in straw) was observed with the application of RDF + Soil application FeSO<sub>4</sub> + ZnSO<sub>4</sub> @ 25 kg ha<sup>-1</sup> (T<sub>7</sub>) and lowest with T<sub>1</sub> (RDF) (2.09 % in seed and 1.36 % in straw) respectively. The K concentration increased at both stages of growth due to zinc and iron fertilization. At the harvest stage the K concentration in seed was higher as compared to that of straw.

The uptake of K in green gram seed and straw ranged from 21.32 kg ha<sup>-1</sup> to 38.02 kg ha<sup>-1</sup> and 16.82 kg ha<sup>-1</sup> to 26.60 kg ha<sup>-1</sup>, respectively. The highest uptake of K was observed in green gram

**Table 3. Effect of micronutrient application on potassium content, potassium uptake in seed and straw and total uptake of green gram after harvest.**

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (%)	Uptake (kg ha <sup>-1</sup> )	Content (%)	Uptake (kg ha <sup>-1</sup> )	
T <sub>1</sub>	2.09	21.32	1.36	16.82	38.14
T <sub>2</sub>	2.38	32.47	1.39	25.36	57.83
T <sub>3</sub>	2.34	25.59	1.41	19.73	45.32
T <sub>4</sub>	2.40	33.96	1.41	25.90	59.87
T <sub>5</sub>	2.37	29.28	1.36	22.50	51.78
T <sub>6</sub>	2.34	27.76	1.39	22.28	50.04
T <sub>7</sub>	2.41	38.02	1.43	26.60	64.63
T <sub>8</sub>	2.30	23.93	1.38	18.46	42.39
T <sub>9</sub>	2.23	23.06	1.38	19.02	42.08
T <sub>10</sub>	2.25	23.98	1.37	18.70	42.68
<b>SE (m) ±</b>	<b>0.06</b>	<b>2.71</b>	<b>0.01</b>	<b>1.23</b>	<b>3.18</b>
<b>CD at 5%</b>	<b>NS</b>	<b>8.06</b>	<b>NS</b>	<b>3.66</b>	<b>9.47</b>

seed (38.02 kg ha<sup>-1</sup>) and straw (26.60 kg ha<sup>-1</sup>) was recorded in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and was found at par with treatment and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum uptake of K in seed (21.32 kg ha<sup>-1</sup>) and in straw (16.82 kg ha<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF).

Total K uptake of green gram (64.63 kg ha<sup>-1</sup>) was maximum in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and was found at par with treatment T<sub>4</sub> (RDF + S.A. Grade-1 micro-nutrient @ 25 kg/ha<sup>-1</sup> + F.A. Grade-2 micro-nutrient @ 0.5 % at 25 and 40 DAS) i.e. (59.87 kg ha<sup>-1</sup>) and treatment T<sub>2</sub> (RDF + S.A. Grade-1 micro-nutrient @ 25 kg/ha<sup>-1</sup>) i.e. (57.83 kg ha<sup>-1</sup>) and superior over rest of the treatments. Whereas, the minimum total uptake of K (38.14 kg ha<sup>-1</sup>) was recorded in treatment T<sub>1</sub> (RDF).

This might be due to the synergistic interaction between zinc and potassium many zinc-dependent enzymes are involved in carbohydrate metabolism in general and leaves in particular, impairment of K in stomata regulation, phloem export of assimilation from the source i.e. the leaves into the sink organs, maintained water balance in the soil-plant-atmosphere continuum. A similar trend was found by Lokhande et al. (2018) in pigeon pea crop.

### 3.4 Iron Content and Uptake by Green Gram

The data presented in Table 4 The highest Fe content in seed (116.66 mg kg<sup>-1</sup>) and in straw (75.56 mg kg<sup>-1</sup>) was recorded with the application

of treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) respectively followed by treatment T<sub>5</sub>, T<sub>4</sub> and T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum Fe content in seed (106.10 mg kg<sup>-1</sup>) and straw (62.37 mg kg<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF).

The uptake of Fe in green gram seed and straw ranged from (1083.14 to 1838.13 kg ha<sup>-1</sup>) and (770.10 to 1408.96 kg ha<sup>-1</sup>), respectively. The highest uptake of Fe was observed in green gram seed (1838.13 kg ha<sup>-1</sup>) and straw (1408.96 kg ha<sup>-1</sup>) and was found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over the rest of the treatments. Whereas, the minimum uptake of Fe in seed (1083.14 kg ha<sup>-1</sup>) and in straw (770.10 kg ha<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF).

Total Fe uptake of green gram (3247.09 kg ha<sup>-1</sup>) was maximum in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) respectively and was found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum total uptake of Fe (1853.23 kg ha<sup>-1</sup>) was recorded in treatment T<sub>1</sub> (RDF). Higher active iron content with foliar spray might be due to the maintenance of Fe in soluble form (Fe<sup>++</sup>) due to the acidity of citric acid. Similar findings were observed by Gahlot et al., (2020) in mung bean crop. Singh et al., (2016) in green gram.

### 3.5 Zinc Content and Uptake by Green Gram

The data on the content and uptake of Zn presented in Table 5 The highest Zn content in

**Table 4. Effect of micronutrient application on iron content, iron uptake in seed and straw and total uptake of green gram after harvest**

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (mg kg <sup>-1</sup> )	Uptake (kg ha <sup>-1</sup> )	Content (mg kg <sup>-1</sup> )	Uptake (kg ha <sup>-1</sup> )	
T <sub>1</sub>	106.10	1083.14	62.37	770.10	1853.23
T <sub>2</sub>	113.80	1550.29	75.66	1377.65	2927.95
T <sub>3</sub>	109.53	1199.50	70.80	993.13	2192.63
T <sub>4</sub>	114.88	1628.70	72.53	1329.40	2958.10
T <sub>5</sub>	115.14	1423.97	75.52	1253.99	2677.95
T <sub>6</sub>	106.72	1254.67	65.33	1037.77	2292.44
T <sub>7</sub>	116.66	1838.13	75.56	1408.96	3247.09
T <sub>8</sub>	110.73	1149.56	72.46	972.88	2122.44
T <sub>9</sub>	106.73	1103.40	66.73	921.54	2024.94
T <sub>10</sub>	112.07	1188.81	71.70	978.90	2167.71
<b>SE (m) ±</b>	<b>1.26</b>	<b>119.33</b>	<b>1.44</b>	<b>55.20</b>	<b>141.63</b>
<b>CD at 5%</b>	<b>3.76</b>	<b>354.56</b>	<b>4.29</b>	<b>164.01</b>	<b>420.82</b>

**Table 5. Effect of micronutrient application on zinc content, zinc uptake in seed and straw and total uptake of green gram after harvest**

Treatments	Seed		Straw		Total Uptake (kg ha <sup>-1</sup> )
	Content (%)	Uptake (kg ha <sup>-1</sup> )	Content (%)	Uptake (kg ha <sup>-1</sup> )	
T <sub>1</sub>	25.51	259.30	21.73	268.55	527.85
T <sub>2</sub>	41.92	568.91	24.78	450.79	1019.70
T <sub>3</sub>	38.04	416.54	24.90	348.59	765.13
T <sub>4</sub>	42.57	599.54	26.86	492.16	1091.70
T <sub>5</sub>	32.89	407.68	23.88	392.27	799.95
T <sub>6</sub>	43.78	518.11	28.23	450.86	968.97
T <sub>7</sub>	43.97	692.68	28.79	536.97	1229.64
T <sub>8</sub>	31.23	323.58	23.18	311.00	634.58
T <sub>9</sub>	38.52	397.48	26.14	360.98	758.46
T <sub>10</sub>	39.53	419.60	26.25	359.03	778.63
<b>SE (m) ±</b>	<b>0.94</b>	<b>40.09</b>	<b>0.77</b>	<b>23.68</b>	<b>53.13</b>
<b>CD at 5%</b>	<b>2.81</b>	<b>119.12</b>	<b>2.29</b>	<b>70.36</b>	<b>157.87</b>

seed (43.97 mg kg<sup>-1</sup>) and in straw (28.79 mg kg<sup>-1</sup>) was recorded with the application of treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) respectively followed by treatment T<sub>6</sub>, T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. the minimum content of Zn in seed (25.51 mg kg<sup>-1</sup>) and in straw (21.73 mg kg<sup>-1</sup>), recorded in treatment T<sub>1</sub> (RDF). The uptake of Zn in green gram seed and straw ranged from (259.30 kg ha<sup>-1</sup> to 692.68 kg ha<sup>-1</sup>) and (268.55 kg ha<sup>-1</sup> to 536.97 kg ha<sup>-1</sup>), respectively. The highest uptake of Zn was observed in green gram seed (692.68 kg ha<sup>-1</sup>) and straw (536.97 kg ha<sup>-1</sup>) and was found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over the rest of the treatments. Whereas, the minimum uptake of Zn in seed (259.30 kg ha<sup>-1</sup>) and in straw (268.55 kg ha<sup>-1</sup>), respectively recorded in treatment T<sub>1</sub> (RDF). Total Fe uptake of green gram (1229.64 kg ha<sup>-1</sup>) was maximum in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) and was

found at par with treatment T<sub>4</sub> and treatment T<sub>2</sub> and superior over rest of the treatments. Whereas, the minimum total uptake of Fe (527.85 kg ha<sup>-1</sup>) was recorded in treatment T<sub>1</sub> (RDF).

As the uptake of the nutrient is a function of its concentration and dry matter production by the crop, higher the zinc concentration in the produce and higher biomass might be the pertinent reason for the increase in the uptake of zinc by green gram due to zinc and iron fertilization. Similar findings were observed by Lokhande et al. (2018) in green gram crop, Gahlot et al. (2020) in mung bean crop.

### 3.6 Physico-Chemical Properties

Representative soil samples were collected from each plot after harvest of green gram crop to study the effect of micronutrients on soil chemical

properties. The results regarding pH, EC, organic carbon and  $\text{CaCO}_3$  are presented in table 3.6.

**Soil pH:** At the harvest stage of crop growth the lowest pH values (8.13) were found in the treatment supplied with  $T_7$  RDF + Soil application  $\text{FeSO}_4 + \text{ZnSO}_4 @ 25\text{kg ha}^{-1}$  respectively, while the highest pH value (8.23) was observed with  $T_1$  (RDF). The decrease in the pH might be due to increased sulphur content in the soil. Similar results were reported by Ranpariya et al. (2017) in calcareous soils and Kamble et al., (2022) in soybean.

**Electric conductivity:** The electrical conductivity of the soil at different growth stages of green gram was not significantly influenced by zinc and iron fertilization. A maximum EC at harvest was observed in  $T_7$  ( $0.24 \text{ dSm}^{-1}$ ) and lowest EC was recorded with  $T_3$ ,  $T_8$  and  $T_{10}$  ( $0.21 \text{ dsm}^{-1}$ ). This slight increase in soil EC might be due to the addition of salts and solubilization of native minerals due to the slight acidification of soils. Such an increase in EC value might be attributed to the release of ions consequent to the maintenance of saturation during the growth of a crop. This could be attributed to the increase of ions like bicarbonates and Fe, Zn and Mn content. Similar findings were reported by Kamble et al., (2022) in soybean and Ranpariya et al., (2017) in calcareous soils.

**Organic carbon:** Maximum organic carbon content (0.65 %) was observed with  $T_7$  (RDF +  $25 \text{ kg ha}^{-1} \text{ FeSO}_4 + 25 \text{ kg ha}^{-1} \text{ ZnSO}_4 \text{ kg ha}^{-1}$ ) and at par with  $T_4$  and  $T_9$  while lowest was observed with control (0.45 %) at harvest, respectively. This increase in organic carbon content might be due to FYM incorporation resulting increased microbial population which hastened the decomposition of organic manure resulting in the increase of organic carbon in soil. Similar results were reported by Kamble et al., (2022) in soybean and Ranpariya et al., (2017).

**Calcium carbonate:** The lowest calcium carbonate content in soil (18.17 %) and (18.27 %) was obtained in  $T_7$  and  $T_5$  respectively as compared to initial calcium carbonate content (18.45%). The treatment  $T_1$  (RDF) recorded the highest calcium carbonate content (18.43%) over the rest of the treatments. The decrease in

calcium carbonate content in the soil might be due to the neutralization of calcium carbonate due to the application of FYM, iron and zinc sulphat and due to excess green gram residue, which upon decomposition might have neutralized calcium carbonate. The result corresponded to the finding of Kamble et al., (2022) in soybean.

### 3.7 Available Macro-Nutrient

Data related to available macronutrient (N, P, and K) content influenced by the application of micronutrient sources with certain treatments is shown Data about the available NPK content of the soil at harvest is presented in Table 7.

**Available nitrogen:** The maximum nitrogen content ( $205.81 \text{ kg ha}^{-1}$ ) was registered with  $T_7$  (RDF +  $25 \text{ kg ha}^{-1} \text{ FeSO}_4 + 25 \text{ kg ha}^{-1} \text{ ZnSO}_4 \text{ kg ha}^{-1}$ ) whereas, the lowest ( $189.00 \text{ kg ha}^{-1}$ ) was observed in  $T_1$  (RDF) at harvest. However, the effect was found to be non-significant. This increase in available nitrogen might be due to enhanced multiplication of microbes by the incorporation of organic manures which catalyze the conversion of organic bound N to inorganic form Similar results were obtained by Kamble et al., (2022) in soybean, Rao et al., (2016), and Ranpariya et al., (2017) in calcareous soils.

**Available phosphorus:** The higher available phosphorus ( $19.26 \text{ kg ha}^{-1}$ ) in soil was observed with treatment  $T_7$  (RDF +  $25 \text{ kg ha}^{-1} \text{ FeSO}_4 + 25 \text{ kg ha}^{-1} \text{ ZnSO}_4 \text{ kg ha}^{-1}$ ) and was found at par with treatment  $T_4$  and treatment  $T_2$  and superior over rest of treatments after harvest of green gram crop. However, the lower available phosphorus ( $17.83 \text{ kg ha}^{-1}$ ) was recorded in treatment  $T_1$  (RDF) in green gram soil. This might be due to the increase in the availability of phosphorus among the treatments due to the rapid solubilization of native and applied  $\text{P}_2\text{O}_5$  as a result of carbonic acid produced due to higher microbial respiration, protection provided by humic, fulvic and humin substances resulting from the organic carbon recycling might explain the reason for higher phosphorus availability. Similar findings were also reported by Lokhande, (2018) on green gram crops. Naveen et al., (2022) in cowpea crop and Ranpariya et al., (2017) in calcareous soil.

**Table 6. Effect of micronutrient application on physico-chemical properties of soil after harvest of green gram**

Treatments	pH	E.C (dSm <sup>-1</sup> )	Organic Carbon (%)	CaCO <sub>3</sub> (%)
T <sub>1</sub>	8.23	0.22	0.45	18.43
T <sub>2</sub>	8.18	0.23	0.51	18.30
T <sub>3</sub>	8.18	0.21	0.44	18.37
T <sub>4</sub>	8.15	0.23	0.55	18.29
T <sub>5</sub>	8.15	0.23	0.36	18.27
T <sub>6</sub>	8.13	0.23	0.51	18.23
T <sub>7</sub>	8.13	0.24	0.65	18.17
T <sub>8</sub>	8.20	0.21	0.51	18.37
T <sub>9</sub>	8.17	0.22	0.56	18.40
T <sub>10</sub>	8.13	0.21	0.51	18.33
SE (m) ±	0.02	0.01	0.03	0.07
CD at 5%	NS	NS	0.11	NS

**Table 7. Effect of micronutrient application on available macro and micro-nutrient in soil after harvest of green gram.**

Treatments	Available macro-nutrients after harvest			Available micronutrient status of soil at harvest			
	N (kg ha <sup>-1</sup> )	P (kg ha <sup>-1</sup> )	K (kg ha <sup>-1</sup> ) 1)	Fe (mg kg <sup>-1</sup> )	Zn (mg kg <sup>-1</sup> ) 1)	Cu (mg kg <sup>-1</sup> ) 1)	Mn (mg kg <sup>-1</sup> )
T <sub>1</sub>	189.00	17.83	465.79	2.19	0.46	0.20	2.31
T <sub>2</sub>	203.26	18.66	476.73	2.31	0.54	0.24	2.42
T <sub>3</sub>	201.53	18.50	474.37	2.24	0.48	0.23	2.35
T <sub>4</sub>	203.46	19.06	477.90	2.34	0.55	0.25	2.39
T <sub>5</sub>	201.84	17.80	474.32	2.88	0.43	0.22	2.33
T <sub>6</sub>	202.34	18.53	476.84	2.23	0.76	0.22	2.35
T <sub>7</sub>	205.81	19.26	478.00	2.92	0.78	0.24	2.38
T <sub>8</sub>	202.55	18.06	473.00	2.23	0.44	0.23	2.34
T <sub>9</sub>	197.90	18.10	473.88	2.26	0.46	0.24	2.35
T <sub>10</sub>	202.61	18.36	476.28	1.87	0.44	0.22	2.36
SE (m) ±	3.37	0.28	2.42	0.13	0.009	0.008	0.04
CD at 5%	NS	0.84	NS	0.39	0.02	NS	NS

**Available potassium:** The perusal of the data presented indicated that the available potassium content of the soil was not significantly influenced by iron and zinc fertilization. Maximum potassium content (478.00 kg ha<sup>-1</sup>) was observed with T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) at the harvest stage. Minimum potassium content (465.79 kg ha<sup>-1</sup>) at harvest stage was observed with T<sub>1</sub> (control). Similar results were reported by Kamble et al., (2022) in soybean, and Ranpariya et al., (2017) in calcareous soils.

### 3.8 Available Micronutrients

The data related to available micronutrient (Fe, Zn, Cu and Mn) content influenced by the application of micronutrient sources with certain treatments is shown below presented in Table 7.

**Available iron:** The maximum available Fe (2.92 mg kg<sup>-1</sup>) after harvest of the crop was observed in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) followed by treatment T<sub>5</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub>) and significantly superior over rest of the treatments in green gram. However, the treatment T<sub>1</sub> (RDF) recorded minimum available Fe (2.19 mg kg<sup>-1</sup>) were observed after harvest of green gram. This increase in available Fe might be due to the application of Fe in soil along with RDF in green gram soil. The results confirm to those of Ajjannavar et al., (2021) in chickpea and Naveen et al. (2022) in cow pea crop.

**Available zinc:** The data showed that the maximum availability of zinc (0.78 mg kg<sup>-1</sup>) was found in treatment T<sub>7</sub> (RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> +

25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> kg ha<sup>-1</sup>) followed by treatment T<sub>6</sub> (RDF + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub>) and significantly superior over rest of the treatments in green gram. The lowest availability of zinc (0.46 mg kg<sup>-1</sup>) was found in treatment T<sub>1</sub> (RDF) after the harvest of the green gram crop. The increase in available zinc content might be due to the addition of zinc fertilizer. A significant increase in zinc content might be because zinc sulphate is more water-soluble and therefore readily available, making its effects visible in DTPA extractable zinc content in the soil. Reported by Kamble et al., (2022) in soybean and Ranpariya et al., (2017) in calcareous soil.

**Available copper:** A slight increase in DTPA copper content with 0.25 mg kg<sup>-1</sup> over the initial value 0.18 mg kg<sup>-1</sup> at harvest was observed. This increase in the available copper content of soil might be due to the solubilization of native copper by organic acids produced from the decomposition of organic matter. Maximum DTPA copper content at harvest (0.25 mg kg<sup>-1</sup>) was observed with T<sub>4</sub> (RDF + S.A. Grade-I micro-nutrient @ 25 kg ha<sup>-1</sup> + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS) while lowest was observed with T<sub>1</sub> (RDF) at harvest (0.20 mg kg<sup>-1</sup>) respectively. Similar results were reported by Ranpariya et al., (2017) in calcareous soils.

**Available manganese:** DTPA manganese content of the soil ranged from 2.31 to 2.42 mg kg<sup>-1</sup> at the harvest stage, respectively. Among all the treatments maximum DTPA manganese content (2.42 mg kg<sup>-1</sup>) at harvest was observed with T<sub>2</sub> (RDF + S.A. Grade-I micro-nutrient @ 25 kg ha<sup>-1</sup>) while the lowest was observed with T<sub>1</sub> RDF control (2.31 mg kg<sup>-1</sup>) at harvest respectively. These findings were in agreement with those reported by Ranpariya et al., (2017) in calcareous soil. A slight increase in DTPA manganese content from the initial to harvest, was observed. This increase in the available manganese content of soil might be due to the solubilization of native manganese by organic acids produced from the decomposition of organic matter and soil fertilization.

## 4. CONCLUSION

### 4.1 Nutrient Content

The concentration of N, P, and K in seed and straw was not significantly affected due to the application of micronutrients. Whereas, the concentration of Fe and Zn in seed and straw

was found significantly maximum with the application of RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> (T<sub>7</sub>). The lowest concentration of N, P, K, S, Fe, and Zn in seed and straw was found with treatment T<sub>1</sub> (RDF).

### 4.2 Total Nutrient Uptake

The highest total uptake of N (88.94 kg ha<sup>-1</sup>), P (14.80 kg ha<sup>-1</sup>), K (64.63 kg ha<sup>-1</sup>), Fe (3247.09 g ha<sup>-1</sup>) and Zn (1229.64 g ha<sup>-1</sup>) were found with treatment T<sub>7</sub> (application of RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub>). The lowest total uptake of N (55.36 kg ha<sup>-1</sup>), P (8.16 kg ha<sup>-1</sup>), K (38.14 kg ha<sup>-1</sup>), Fe (1853.23 g ha<sup>-1</sup>) and Zn (527.85 g ha<sup>-1</sup>) were found with treatment T<sub>1</sub> (RDF).

### 4.3 Physio-Chemical Properties of Soil

The result regarding physio-chemical properties of soil like pH, EC, and CaCO<sub>3</sub> was not affected significantly due to soil and foliar application of micronutrient sources in green gram. However, the highest organic carbon content (0.65 percent) in soil was noted due to the application of RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub> (T<sub>7</sub>) followed by treatment T<sub>9</sub> and T<sub>4</sub>. Whereas, the lowest organic carbon (0.45 percent) was recorded with treatment T<sub>1</sub> (RDF).

### 4.4 Available Nutrients in Soil

Available nutrients in soil like N, K, Cu, and Mn were not affected significantly due to soil and foliar application of micronutrient sources in green gram. But the significant influence of P<sub>2</sub>O<sub>5</sub> (19.26 kg ha<sup>-1</sup>), Fe (2.92 mg kg<sup>-1</sup>) and Zn (0.78 mg kg<sup>-1</sup>) was found maximum in treatment (application of RDF + 25 kg ha<sup>-1</sup> FeSO<sub>4</sub> + 25 kg ha<sup>-1</sup> ZnSO<sub>4</sub>) T<sub>7</sub>. It also observed that the available nutrients in post-harvest soil samples were higher than initial soil samples.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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