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Fortification of Zinc and Iron through spray in mungbean (*Vigna radiata*)

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Abstract

An agronomic investigation entitled 'Fortification of Zinc and Iron through spray in mungbean (*Vigna radiata*)' was carried out at experiment farm Agricultural Research Station, Badnapur, Vasantrao Naik Marathwada Krishi Vidhyapeeth, Parbhani during *kharif*, 2023. The experiment was laid out in randomized block design with three replications. The soil was clayey in texture having 30 cm depth with moderate moisture holding capacity which was good for normal growth of the crop. The recommended mungbean cv. BM 2003-2 was tested for this experiment along with these eight treatments. The treatment included with (T_1) 0.5% $ZnSO_4$ - spray at flower initiation, (T_2) 0.5% $ZnSO_4$ - spray at flower and pod initiation, (T_3) 0.5% $FeSO_4$ - spray at flower initiation, (T_4) 0.5% $FeSO_4$ - spray at flower and pod initiation, (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation, (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation, (T_7) 25 kg ha^{-1} $ZnSO_4$ - through soil application and (T_8) 10 kg ha^{-1} $FeSO_4$ - through soil application. The gross plot size of experiment plot was 5.4×5.0 m^2 and net plot size was 4.8×4.8 m^2. The crop was sown by dibbling method at spacing 30×10 cm^2.

The effect of different treatments on yield and yield attributing characters *viz.*, number of pods $plant^{-1}$, number of seeds $plant^{-1}$, 100 seed weight, seed yield $plant^{-1}$, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) were considerably higher with application of treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation and found at par with treatment (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and lower in the treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation. Among the treatments, the maximum seed yield (1131 kg ha^{-1}) was recorded with the application of treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation and found significantly higher with treatment (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and rest of the treatments. The lowest seed yield (695 kg ha^{-1}) was recorded in treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation.

On the basis of economics, highest gross monetary returns and net monetary returns were recorded with the application of the treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (₹ 80165 ha^{-1}) followed by treatment (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation. The minimum gross monetary return and net monetary return was observed with application of treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (₹ 49393 ha^{-1}) in mungbean crop. Similar trend was observed in case of benefit: cost ratio was obtained with treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (2.15) and minimum benefit: cost ratio was concluded with the application of treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (1.40).

Keywords: Mungbean, fortification, zinc sulphate, ferrous sulphate, foliar, soil, flower initiation, pod initiation, seed, stover

Introduction

Mungbean is one of the important pulse crops grown in arid and semi-arid region of the country. Among the pulses grown in India, mungbean ranks third after chickpea and pigeonpea because of its adaptation to short growth duration, low water requirement, soil fertility and is favoured for consumption due to its easy digestibility and low production of flatulence (Sahil and Bandopadhya, 2007) [11]. Mungbean serves as a green manure crop, leveraging its leguminous nature to fix atmospheric nitrogen at a rate of 30 - 40 kg N ha^{-1}. Its green plants are used as fodder after removing the mature pods. Mungbean is an excellent source of protein 25% with high quantity of lysine 4600 mg N^{-1} and tryptophan 60 mg N^{-1} and consumed as whole grain as well as dal in variety of ways for table purposes. Additionally, it plays a role in soil erosion prevention. Due to its short duration, it seamlessly integrates into various intensive crop rotations. Mungbean is employed as a rotation crop within rice and rice - wheat cropping systems, while sugarcane and maize are two other crops that are commonly intercropped.

Zinc is essential element for crop production and growth development of plant (Ali and Nesa, 2012) [1]. Zinc deficiency can be particularly severe in calcareous, organic matter-deficient, arid, and semi-arid soils. Zinc plays a crucial role in various plant metabolic processes, including the development of cell walls, respiration, photosynthesis, chlorophyll formation, enzyme activity, and other biochemical functions.

Iron serves as a structural component in various molecules, such as porphyrins, cytochromes, haems, hematin, ferrochrome, and leghaemoglobin. These substances play crucial roles in oxidation-reduction reactions involved in respiration and photosynthesis. Sulphur plays a vital role in regulating the metabolic and enzymatic processes including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation, energy transformation, activation of enzymes and also in carbohydrate metabolism which reflected in increased yield.

Soil application of fertilizer is the most straight forward method for addressing micronutrient deficiencies. However, its success and sustainability are not guaranteed, due to agronomic and economic factors. Challenges include low availability of micronutrient elements caused by top soil drying, sub soil constraints, interactions with diseases, and the high cost of fertilizer, particularly in developing countries. Foliar spraying is a new method for crop feeding in which micronutrients in the form of liquid are used on leaves (Nasiri *et al.* 2010) [8].

Agronomic biofortification presents a rapid approach to enhance micronutrient concentrations, proving to be more attainable than breeding methods. This strategy offers a swift remedy for addressing mineral deficiencies, simultaneously complementing ongoing breeding initiatives. Among the diverse techniques of biofortification, foliar application emerges as the optimal means of elevating micronutrient levels in crops.

Material and Methods

The field experiment was conducted at Experimental farm, Department of Agronomy, Agricultural Research Station, Badnapur. The topography of experimental plot was fairly levelled. The soil was medium black in colour, high moisture retentive, clayey deep and fairly well drained. The soil of experimental plot was clayey in texture, low in organic carbon, low in nitrogen, moderate in available phosphorus, high in potash and slightly alkaline in reaction.

The seed of mungbean variety BM 2003-2 was collected from Agriculture Research Station, Badnapur. Mungbean was sown on 02 July 2023. The sowing was done by dibbling with 2 seeds per hill at a distance of row to row 30 cm and plant to plant 10 cm (30 cm x 10 cm) at about 4.0 cm depth.

The experimental plot was laid out in Randomized Block Design (RBD) design with eight treatments and three replications. The randomly allotted treatments were (T_1) 0.5% $ZnSO_4$ - spray at flower initiation; (T_2) 0.5% $ZnSO_4$ - spray at flower and pod initiation; (T_3) 0.5% $FeSO_4$ - spray at flower initiation; (T_4) 0.5% $FeSO_4$ - spray at flower and pod initiation; (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation; (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation; (T_7) 25 kg ha^{-1} $ZnSO_4$ - through soil application and (T_8) 10 kg ha^{-1} $FeSO_4$ - through soil application.

Results and Discussion

A) Yield attributes of mungbean influenced by various treatments

During the field experiment the yield attributes including number of pods $plant^{-1}$, number of seeds pod^{-1},100 seed weight (g), Seed yield $plant^{-1}$ (g), Seed yield (kg ha^{-1}), Stover yield (kg ha^{-1}) and Harvest index (%) were significantly influenced by various treatments.

Number of pods $plant^{-1}$

Maximum number of pods $plant^{-1}$ of mungbean was recorded with (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation which was significantly higher than other treatments but found at par with (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation as shown in Table 1. It was followed by (T_8) 10 kg ha^{-1} $FeSO_4$ - through soil application, (T_7) 25 kg ha^{-1} $ZnSO_4$ - through soil application, (T_4) 0.5% $FeSO_4$ - spray at flower and pod initiation and (T_2) 0.5% $ZnSO_4$ - spray at flower and pod initiation. The number of pods $plant^{-1}$ recorded with (T_3) 0.5% $FeSO_4$ - spray at flower initiation and (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (7.48) were less as compared to rest other treatments.

These findings align with the results observed by Sasane *et al.* (2023) [15] on mungbean to evaluate physiological responses of ferrous sulphate and zinc sulphate and reported significant higher number of pods $plant^{-1}$. The positive effect on number pods $plant^{-1}$ is attributed to the favourable influence of zinc application on nutrient metabolism, biological activity and growth parameters. Ferrous is involved in the chlorophyll synthesis process. Therefore, the application of zinc and ferrous resulted in taller plants and higher enzyme activity, which in turn promotes pod growth (Michail *et al.* 2004) [7].

Number of seeds pod^{-1}

During harvest number of seeds pod^{-1} of mungbean were recorded with (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (14.92); which was significantly higher than other treatments but found at par with (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation as shown in Table 1. It was followed by (T_8) 10 kg ha^{-1} $FeSO_4$ - through soil application; (T_7) 25 kg ha^{-1} $ZnSO_4$ - through soil application; (T_4) 0.5% $FeSO_4$ - spray at flower and pod initiation and (T_2) 0.5% $ZnSO_4$ - spray at flower and pod initiation. Less number of seeds pod^{-1} were recorded with (T_3) 0.5% $FeSO_4$ - spray at flower initiation (11.77) and (T1) 0.5% $ZnSO_4$ - spray at flower initiation (11.00) as compared to rest of the treatments. Similar results were revealed by Soni and Kushwaha (2020) [16].

100 seed weight (g)

Maximum value of 100 seed weight was recorded by the treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (5.12 g); which was found at par with (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and found significantly superior over rest of the treatments as shown in Table 1. Overall growth of the plant might be due to a greater number of new accumulating sinks and role of zinc in metabolic activity. Higher photosynthesis rate, translocation, assimilation metabolites in the sink ultimately results in increasing the size of seed. This finding aligns with the results of Banjara and Majgahe (2019) [3] and Pal *et al.* (2019) [9].

Seed yield $plant^{-1}$ (g)

The treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation recorded maximum value of seed yield $plant^{-1}$ (3.23 g), which was found at par with the treatment (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and found significantly superior over rest of the treatments as shown in Table 1. The increase in yield attributes might have been owing to better utilization of resources under application of zinc sulphate and ferrous sulphate. Similar results were concluded by Anitha *et al.* (2005) [2] in mungbean.

Seed yield (kg ha^{-1})

Treatment (T_6) with 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (1131 kg ha^{-1}) was at par with (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and found significantly superior over rest of the treatments as shown in Table 2. The lowest seed yield kg ha^{-1} was recorded by the treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (695 kg ha^{-1}).

Seed yield is a quantitative trait that reflects the cumulative physiological activities of a plant. Foliar application of nutrients, particularly zinc sulphate and iron sulphate at the stages of flower initiation and pod initiation, may facilitate the efficient translocation of photosynthates from source to sink. Additionally, the application of Zn and Fe significantly enhanced the chlorophyll, nitrogen, phosphorus, and potassium content in the leaves, which may have contributed to the increased yield was observed in this study. Similarly, the highly efficient in increasing seed yield of mungbean exhibiting maximum values were recorded by Dhaliwal *et al.* (2023) [5], Soni and Kushwaha (2020) [16] and Barla *et al.* (2023) [4].

Stover yield (kg ha^{-1})

The maximum value of stover yield kg ha^{-1} was recorded by the treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (2532 kg ha^{-1}) which was found at par with (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and significantly superior over rest of the treatments as shown in Table 2. The similar results were found by Soni and Kushwaha (2020) [16] and Saini and Singh (2017) [12], who observed that foliar application of ferrous sulphate and zinc sulphate in mungbean recorded maximum value of stover yield (kg ha^{-1}).

Harvest index (%)

The treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (30.86%) recorded maximum value of harvest index with general mean of 28.20 as shown in Table 2. Whereas, the lowest value of harvest index was recorded by the treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (26.87%). From overall results, it can be stated that foliar application of ferrous sulphate and zinc sulphate with different concentrations improved the morpho-physiological, yield and yield attributing characters and ultimately yield. These findings align with the results observed by Purushottam *et al.* (2018) [10] and Sasane *et al.* (2023) [15].

Table 1: No. of pods plant^{-1}, no. of seeds pods^{-1}, 100 seed weight (g) and seed yield plant^{-1} influenced by various treatments of mungbean

Sr. no.	Treatment details	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Seed yield plant^{-1} (g)
T_1	0.5% $ZnSO_4$ - Spray at flower initiation	7.48	11.00	4.11	2.00
T_2	0.5% $ZnSO_4$ - Spray at flower and pod initiation	8.21	12.45	4.41	2.42
T_3	0.5% $FeSO_4$ - Spray at flower initiation	7.53	11.77	4.27	2.07
T_4	0.5% $FeSO_4$ - Spray at flower and pod initiation	8.33	12.76	4.54	2.52
T_5	0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower initiation	9.45	14.88	4.83	2.95
T_6	0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower and pod initiation	9.63	14.92	5.12	3.23
T_7	25 kg ha^{-1} $ZnSO_4$ - through soil application	8.51	13.18	4.60	2.64
T_8	10 kg ha^{-1} $FeSO_4$ - through soil application	8.55	13.32	4.70	2.75
	SE (m) ±	0.32	0.31	0.13	0.11
	C.D. at 5%	0.98	0.95	0.40	0.35
	General Mean	8.46	13.03	4.57	2.57

Table 2: Seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) influenced by various treatments of mungbean

Sr. no.	Treatment details	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1	0.5% $ZnSO_4$ - Spray at flower initiation	695	1890	26.87
T_2	0.5% $ZnSO_4$ - Spray at flower and pod initiation	787	2091	27.33
T_3	0.5% $FeSO_4$ - Spray at flower initiation	725	1951	27.08
T_4	0.5% $FeSO_4$ - Spray at flower and pod initiation	882	2324	27.52
T_5	0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower initiation	1031	2518	29.04
T_6	0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower and pod initiation	1131	2532	30.86
T_7	25 kg ha^{-1} $ZnSO_4$ - through soil application	922	2345	28.23
T_8	10 kg ha^{-1} $FeSO_4$ - through soil application	963	2401	28.62
	SE (m) ±	35	41	0.47
	C.D. at 5%	105	124	1.44
	General Mean	892	2257	28.20

B) Economics influenced by various treatments in mungbean

Data pertaining to the cost of cultivation, gross monetary returns, net monetary returns and benefit: cost ratio (B:C ratio) of mungbean under different treatments is furnished in Table 3.

Cost of cultivation

The lowest cost of cultivation was noted in (T_8) 10 kg ha^{-1} $FeSO_4$ - through soil application ₹ 34760 ha^{-1} and highest in (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation ₹ 37120 ha^{-1}. The general mean of cost of cultivation recorded was ₹ 35547 ha^{-1} as shown in Table 3.

Gross monetary returns

The differences in gross monetary returns were significantly influenced by application of different treatments. Maximum gross monetary return was recorded by treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (₹ 80165 ha^{-1}) and it was found at par with treatment (T_5) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower initiation and followed by rest of the treatments as shown in Table 3. The similar results were noted by Sajid *et al.* (2017) [14] in okra.

Net monetary returns

The net monetary returns of mungbean were significantly influenced by the application of various treatments as shown in Table 3. The maximum value of net monetary return was recorded by treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (₹ 42955 ha^{-1}) and minimum value of net monetary return was recorded by the treatment (T_1) 0.5% $ZnSO_4$ - spray at flower initiation. These findings were supported by Teja *et al.* (2022) [17], who concluded that the net monetary returns were maximum recorded in mungbean by the foliar application of zinc sulphate, single super phosphate and ferrous sulphate.

Benefit: cost ratio (B:C ratio)

Benefit: cost ratio of mungbean was influenced by various treatments as shown in Table 3. The maximum and minimum values of benefit: cost ratio of mungbean was recorded by the treatment (T_6) 0.5% $ZnSO_4$ and $FeSO_4$ - spray at flower and pod initiation (2.15) and (T_1) 0.5% $ZnSO_4$ - spray at flower initiation (1.40), respectively. These results are in conformity with those observed by Atul Kumar Saini (2017) [13] and Khan *et al.* (2023) [6].

Table 3: Cost of cultivation (₹ ha^{-1}), gross monetary returns (₹ ha^{-1}), net monetary returns (₹ ha^{-1}) and benefit: cost ratio

Sr. no.	Treatment details	Cost of cultivation (₹ ha^{-1})	Gross monetary returns (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	Benefit: Cost Ratio
T_1	0.5% $ZnSO_4$ - Spray at flower initiation	35080	49393	14313	1.40
T_2	0.5% $ZnSO_4$ - Spray at flower and pod initiation	35780	55894	20114	1.56
T_3	0.5% $FeSO_4$ - Spray at flower initiation	35050	51505	16455	1.47
T_4	0.5% $FeSO_4$ - Spray at flower and pod initiation	35720	62645	26925	1.75
T_5	0.5% $ZnSO_4$ and $FeSO_4$ -Spray at flower initiation	35750	73182	37432	2.04
T_6	0.5% $ZnSO_4$ and $FeSO_4$ -Spray at flower and pod initiation	37210	80165	42955	2.15
T_7	25 kg ha^{-1} $ZnSO_4$ - through soil application	35030	65506	30476	1.87
T_8	10 kg ha^{-1} $FeSO_4$ - through soil application	34760	68382	33622	1.96
	SE (m) ±	N.S.	2543	1876	N.S.
	CD at 5%	N.S.	7679	5663	N.S.
	General Mean	35547	63238	27786	1.78

Conclusion

Results obtained during investigation inferred some conclusions which are furnished below:

1. The application of 0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower and pod initiation was found appropriate for achieving increased growth and yield attributes both in terms of seed yield and stover yield of mungbean.
2. The foliar application of zinc (Zn) and iron (Fe) resulted in favourable changes in the production of mungbean.
3. Based on economics, application of 0.5% $ZnSO_4$ and $FeSO_4$ - Spray at flower and pod initiation gave maximum gross monetary return and net monetary return.

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