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Effect of zinc and iron application on yield, nutrient content and nutrient uptake by mothbean (*Vigna aconitifolia* L.) in Northern dry zone of Karnataka

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Abstract
A field experiment was conducted during 2022-23 *Kharif* season at Regional Agricultural Research Station, Vijayapura to study the influence of zinc and iron on growth and yield of mothbean. The experiment was laid out in a split plot design with four levels of zinc in main plot (0, 2.5, 5 and 7.5 kg ha^{-1}) and four levels of iron in sub plot (0, 2.5, 5, 7.5 kg ha$^{-1)}$ with one absolute control. Application of zinc sulphate alone @ 7.5 kg ha^{-1} and iron sulphate alone @ 7.5 kg ha^{-1} recorded maximum plant height, dry matter accumulation, number of pods per plant, test weight, grain yield, straw yield, nutrient content of zinc, iron and uptake of zinc and iron of mothbean. The combined application of zinc sulphate and iron sulphate each @ 7.5 kg ha^{-1} recorded no significant difference however, numerically higher values of growth parameters, yield parameters and nutrient uptake of mothbean was noted. All the growth, yield parameters and nutrient uptake increased with increase in zinc sulphate and iron sulphate levels.

Keywords: Growth, iron, mothbean, yield, zinc

Introduction

Pulses are grown across the globe with a significant production hub in Asia, notably in India that holds a vital role in overall human nutrition and health. These dried legumes cover a diverse range including beans, lentils, peas and chickpeas, collectively providing an array of essential nutrients. Pulses are exceptional sources of quality protein, in addition to being utilized for their unique medicinal properties, as good quality fodder for livestock, enriching soil as a result of symbiotic relationship with nitrogen-fixing bacteria and mitigating greenhouse emissions (Lemke *et al.*, 2007) [13]. Moth bean, scientifically known as *Vigna aconitifolia* L., belongs to the legume genus *Vigna* and possesses remarkable adaptability to arid and semi-arid regions. Its ability to thrive across diverse eco-geographical zones as well as harsh climatic conditions, particularly in the Indian subcontinent, highlights its significant importance. This legume goes by several names, like mat bean, math, mattenbohne, matki, dew bean, Turkish gram, and haricot papillon. Moth bean takes center stage primarily for its protein-rich seeds, sprouts, and edible green pods, which serve as a valuable source of nutrition. Moth bean [*Vigna aconitifolia* (Jacq)], is believed to have originated in the regions of India, Pakistan, Myanmar, and Sri Lanka, according to De Candolle (1986) [2]. Moth bean's cultivation is particularly concentrated in arid and semi-arid regions, with a majority taking place in the North-Western states of India like Rajasthan, Maharashtra, Gujarat, Punjab, Haryana, Jammu and Kashmir, Madhya Pradesh, and Uttar Pradesh. Among these, Rajasthan stands out as the top contributor in terms of moth bean production. (Gupta *et al.*, 2016; Viswanatha *et al.*, 2016) [7, 21].

Micronutrient deficiency is a severe problem in soil and plants worldwide (Imtiaz *et al.*, 2010) [9]. Micronutrients like iron (Fe), zinc (Zn), boron (B), and molybdenum (Mo) exert the most significant influence on pulse crop production. Up until the 1980's, zinc deficiency was the primary micronutrient limitation affecting crop production. However, as high yielding crop varieties were developed, chemical fertilizers gained attention, and cultivation practices became more intensive and deficiencies in other micronutrients started to emerge vaguely. Among the cationic micronutrients, zinc (Zn) remains the most deficient, with approximately 49% of soils showing this deficiency. Following closely behind are iron (Fe), manganese (Mn), and copper (Cu), which are currently deficient in 12 per cent, 4 per cent, and 3 per cent of soils, respectively. Micronutrients are those vital elements required by plants in very minimal quantities, these play a pivotal role in overall plant development. Inadequate supplies of these nutrients can result in micronutrient deficiency, which is a severe problem in soil and plants worldwide. Consequently, gaining a thorough understanding of micronutrient deficiencies and exploring methods to rectify them becomes of paramount importance. The deficiency of Zn and Fe is most commonly observed in Northern Dry Zone of Karnataka. Keeping in view the important role of zinc and iron in crop production, current study was carried out with chelated application of Zn and Fe to overcome the micronutrient deficiencies in soil and help the increase in crop growth and yield.

Methodology

The field experiment was carried out at Regional Agricultural Research Station (RARS), Vijayapura during *kharif* 2022, under Northern Dry Zone of Karnataka (Zone 3), located at a latitude 16^0 49^1 North, longitude $75^0 43^1$ East and an altitude of 593.8 m above mean sea level (MSL). The experiment was carried out by adopting split plot design with four main plots which consisted different levels of zinc sulphate *viz.*, MP_1- 0 kg ha^{-1} $ZnSO_4$, MP_2- 2.5 kg ha^{-1} $ZnSO_4$, MP_3- 5 kg ha^{-1} $ZnSO_4$ and MP_4- 7.5 kg ha^{-1} $ZnSO_4$ and four sub plots which consisted of different levels of iron sulphate *viz.*, SP_1- 0 kg ha^{-1} $FeSO_4$, SP_2- 2.5 kg ha^{-1} $FeSO_4$, SP_3- 5 kg ha^{-1} $FeSO_4$ and SP_4- 7.5 kg ha^{-1} $FeSO_4$ replicated thrice and one absolute control. Zinc sulphate and iron sulphate were chelated with vermicompost in 1:1 ratio and applied 15 days before sowing. Seeds of KBMB-1 variety at a seed rate of 15 kg ha^{-1} was used. The observations related to growth and yield parameters were recorded at regular interval of time during the crop growth period and data were subjected to standard statistical analysis. The experimental site consisted of shallow *Inceptisol* having clay texture, with a pH of 8.31, low in available nitrogen (175 kg ha^{-1}), medium in available phosphorus (31.05 kg ha^{-1}), and high in potassium (362.0kg ha^{-1}). The soils were deficient in DTPA extractable micronutrients viz., zinc (0.48 mg kg^{-1}) and iron (2.78 mg kg^{-1}). The plant samples collected at harvest stage were washed with distilled water, the samples were shade dried initially and then oven dried at 60ºC temperature and powdered. The representative dry samples of seed and straw were analysed for ascertaining micronutrient content (Zn and Fe). The seed and straw samples were digested in di-acid mixture (HNO_3: $HClO_4$, 9:4 v/v). The nutrient uptake by seed and straw were calculated by multiplying nutrient content with seed and straw yield (kg ha^{-1}) respectively and data was analysed statistically to draw suitable inference as per standard ANOVA technique described by Gomez and Gomez (1984) [6].

Results and discussion

Plant height and dry matter accumulation

The results pertaining to plant height and dry matter accumulation at harvest is presented in Table 1. It was evident from the results that plant height and dry matter accumulation was significantly influenced by the application of zinc sulphate and iron sulphate. The application of zinc sulphate @ 7.5 kg ha^{-1} alone, recorded highest plant height and dry matter accumulation of 46.81 cm and 19.33 g plant^{-1}. Similarly, application of iron sulphate @ 7.5 kg ha^{-1} alone recorded a plant height of 45.02 cm and dry matter accumulation of 18.79 g plant^{-1}. The combined application of zinc sulphate and iron sulphate @ 7.5 kg ha^{-1} each did not show any significant differences, however numerically higher values of plant height and dry matter accumulation were recorded with combined application of zinc sulphate and iron sulphate @ 7.5 kg ha^{-1}. This increase in plant height and dry matter accumulation might be due to the key role of zinc in various metabolic activities, cellular growth, differentiation, chlorophyll synthesis and maintenance of chlorophyll structure and also the supremacy of chelated zinc sulphate in balanced supply of zinc to the crop, which might have contributed for the vigorous growth of plants and also helped in developing extensive root system leading to enhanced uptake of nutrients and thus increasing in plant height. Similar findings were also reported by Gidaganti *et al.* (2019) [4] who revealed that zinc and iron application @ 25 kg ha^{-1} and 20 kg ha^{-1} in green gram crop recorded higher plant height. Higher dry matter accumulation was recorded due to higher rate of photosynthesis owing to stable chlorophyll structure as influenced by iron. Similar trend of results was also noticed by Singh *et al.* (2016) [18].

Yield parameters

The various yield parameters of mothbean as influenced by different levels of zinc sulphate and iron sulphate alone and their combinations are presented in Table 1. The yield parameters such as number of pods per plant, pod length and test weight (1000 seeds) showed significant difference with the application of different levels of zinc sulphate and iron sulphate alone. The application of zinc sulphate @ 7.5 kg ha^{-1} recorded higher number of pods per plant (24.01), greater pod length (7.30 cm), and test weight (21.42 g). Similarly, iron sulphate application @ 7.5 kg ha^{-1} alone recorded significantly higher number of pods per plant (23.39), pod length (7.20 cm) and test weight (21.10 g). The interaction effect was found to be non-significant. This marked advancement in yield contributing parameters might be due to enhanced growth parameters *viz.*, plant height and dry matter accumulation as zinc has a major role in auxin production as well as a component of carbonic anhydrase and several dehydrogenase enzymes and also due to the application of iron sulphate in chelated form which has enhanced the plant development through proper balanced nutrition and also improving the availability of both macro and micronutrient.

Table 1: Influence of different levels of zinc sulphate and iron sulphate on growth and yield attributes of mothbean

Treatments	Plant height (cm)	Dry matter accumulation (g plant^{-1})	Number of pods per plant	Test weight 1000 seeds (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Zinc sulphate levels (M)						
$ZnSO_4$ @ 0 kg ha^{-1} (MP_1)	32.13	16.49	18.99	18.61	571	1764
$ZnSO_4$ @ 2.5 kg ha^{-1} (MP_2)	39.72	17.43	21.77	19.84	651	1963
$ZnSO_4$ @ 5 kg ha^{-1} (MP_3)	42.64	18.29	22.86	20.12	684	2030
$ZnSO_4$ @ 7.5 kg ha^{-1} (MP_4)	46.81	19.33	24.01	21.42	721	2119
S. Em.±	1.15	0.54	0.62	0.42	15.57	48.61

C.D (0.05)	3.99	1.87	2.15	1.47	53.87	168.22
Iron sulphate levels (S)						
$FeSO_4$ @ 0 kg ha^{-1} (SP_1)	34.88	16.87	20.02	18.95	602	1840
$FeSO_4$ @ 2.5 kg ha^{-1} (SP_2)	38.68	17.49	21.58	19.52	648	1947
$FeSO_4$ @ 5 kg ha^{-1} (SP_3)	42.72	18.37	22.65	20.42	682	2026
$FeSO_4$ @ 7.5 kg ha^{-1} (SP_4)	45.02	18.79	23.39	21.10	696	2063
S. Em.±	1.10	0.42	0.48	0.54	15.72	38.61
C.D (0.05)	3.22	1.23	1.39	1.57	45.89	112.70
Interactions (M×S)						
MP_1SP_1	30.08	16.29	18.54	18.13	562	1737
MP_1SP_2	31.13	16.37	18.66	18.27	565	1749
MP_1SP_3	32.77	16.60	18.97	19.00	575	1776
MP_1SP_4	34.53	16.69	19.82	19.03	583	1792
MP_2SP_1	35.30	16.70	20.19	19.03	594	1822
MP_2SP_2	39.29	17.27	21.95	19.46	654	1972
MP_2SP_3	41.00	17.67	22.27	19.85	670	2004
MP_2SP_4	43.28	18.08	22.66	21.02	687	2053
MP_3SP_1	36.00	17.20	20.32	19.20	616	1869
MP_3SP_2	40.14	17.28	22.17	19.41	661	1985
MP_3SP_3	46.27	19.10	24.18	20.42	721	2104
MP_3SP_4	48.15	19.58	24.77	21.44	741	2163
MP_4SP_1	38.14	17.30	21.03	19.43	637	1930
MP_4SP_2	44.15	19.07	23.55	20.92	711	2083
MP_4SP_3	50.82	20.11	25.17	22.41	763	2220
MP_4SP_4	54.13	20.82	26.30	22.91	774	2243
S. Em.±	2.21	0.84	0.95	1.08	31.44	77.22
C.D (0.05)	NS	NS	NS	NS	NS	NS
Absolute control	22.4	13.4	15.7	17.0	320	1390
S. Em.±	2.18	0.88	0.99	1.01	30.57	94.34
C.D (0.05)	6.29	2.54	2.85	2.90	88.06	271.76

Throughout the growth period, especially during the reproductive phase which might have contributed in increasing the yield stimulating parameters. Boradkar *et al*., 2023 [1] reported that the enhanced performance of various yield attributes, including pod quantity, seeds per pod, pod length, and 1000 seed test weight, can be attributed to the increased transport of photosynthetic products from the source to developing seeds. This improved transport is a direct outcome of micronutrient application, which may also explain the augmented seed weight. Similar research findings were recorded by Misal (2018) [14], Gidaganti *et al.* (2019) [4], Kuldeep *et al.* (2018) [11] and Vinodkumar *et al.* (2020) [20] in greengram.

Grain and Straw yield

The application of different levels of zinc sulphate and iron sulphate significantly influenced the the grain and straw yield of mothbean and the results are presented in Table 1. Significantly higher grain yield of 721 kg ha^{-1} and straw yield of 2119 kg ha^{-1} was recorded with application of zinc sulphate @ 7.5 kg ha^{-1} alone. Among the different iron sulphate levels, application of iron sulphate @ 7.5 kg ha^{-1} recorded significantly higher grain yield of 696 kg ha^{-1} and straw yield of 2063 kg ha^{-1}. However, among the different combinations of zinc sulphate and iron sulphate, grain and straw yield was found to be non-significant. The increase in the grain and staw yield of mothbean crop is due to application of optimum dose of zinc sulphate and iron sulphate after chelation with vermicompost. Also the proper channelization of photosynthates during the reproductive stage of crop might have been influenced by zinc, since it is involved in electron transport system. Zinc application induced better root growth and increased sink pool (pod numbers plant^{-1}) and ultimately achieved higher seed yield in chickpea (Krishna and George, 2017) [10]. The enhanced iron accessibility to the plant could have potentially activated several enzymatic and metabolic processes, consequently enhancing the crop's yield. Similar findings were also reported by Trivedi *et al.* (2011) [19].

Table 2: Influence of different levels of zinc sulphate and iron sulphate on zinc and iron content of grain and straw in mothbean

	Zinc content (mg kg^{-1})		Iron content (mg kg^{-1})	
Treatments	**Grain**	**Straw**	**Grain**	**Straw**
Zinc sulphate levels (M)				
$ZnSO_4$ @ 0 kg ha^{-1} (MP_1)	50.64	26.30	118.9	91.77
$ZnSO_4$ @ 2.5 kg ha^{-1} (MP_2)	52.82	27.13	123.3	95.62
$ZnSO_4$ @ 5 kg ha^{-1} (MP_3)	54.62	28.62	126.2	100.04
$ZnSO_4$ @ 7.5 kg ha^{-1} (MP_4)	56.23	30.15	136.1	107.79
S. Em.±	0.96	0.75	2.25	2.44
C.D (0.05)	3.32	2.60	7.79	8.44
Iron sulphate levels (S)				
$FeSO_4$ @ 0 kg ha^{-1} (SP_1)	51.35	27.13	120.8	92.79
$FeSO_4$ @ 2.5 kg ha^{-1} (SP_2)	52.87	27.19	122.7	95.31
$FeSO_4$ @ 5 kg ha^{-1} (SP_3)	54.71	28.63	128.4	101.57

$FeSO_4$ @ 7.5 kg ha^{-1} (SP_4)	55.39	29.26	132.6	105.56
S. Em.±	0.97	0.55	2.12	2.06
C.D (0.05)	2.83	1.60	6.18	6.00
Interactions (M×S)				
MP_1SP_1	50.05	26.06	116.9	90.23
MP_1SP_2	50.67	26.04	118.5	91.58
MP_1SP_3	50.88	26.44	119.4	92.45
MP_1SP_4	50.95	26.67	120.9	92.83
MP_2SP_1	51.21	26.70	121.3	93.26
MP_2SP_2	52.31	27.01	122.6	95.27
MP_2SP_3	53.58	27.41	124.3	96.89
MP_2SP_4	54.19	27.42	125.1	97.06
MP_3SP_1	52.04	27.57	122.3	93.44
MP_3SP_2	53.03	27.19	123.1	96.04
MP_3SP_3	56.35	29.42	128.8	102.11
MP_3SP_4	57.08	30.32	130.6	108.58
MP_4SP_1	52.09	28.20	122.6	94.23
MP_4SP_2	55.45	28.51	126.7	98.35
MP_4SP_3	58.03	31.26	141.3	114.81
MP_4SP_4	59.36	32.65	153.8	123.78
S. Em.±	1.94	1.10	4.23	4.11
C.D (0.05)	NS	3.20	NS	12.01
Absolute control	44.06	22.5	103.3	78.6
S. Em.±	2.05	1.20	4.16	4.16
C.D (0.05)	5.92	3.47	11.99	11.97

Table 3: Influence of different levels of zinc sulphate and iron sulphate on zinc and iron uptake in grain and sraw of mothbean

	Zinc uptake (kg ha^{-1})		Iron uptake (kg ha^{-1})	
Treatments	**Grain**	**Straw**	**Grain**	**Straw**
Zinc sulphate levels (M)				
$ZnSO_4$ @ 0 kg ha^{-1} (MP_1)	28.93	46.40	67.93	161.9
$ZnSO_4$ @ 2.5 kg ha^{-1} (MP_2)	34.44	53.28	80.34	187.8
$ZnSO_4$ @ 5 kg ha^{-1} (MP_3)	37.49	58.23	86.53	203.7
$ZnSO_4$ @ 7.5 kg ha^{-1} (MP_4)	40.70	64.11	98.73	229.8
S. Em.±	1.01	1.60	2.79	6.46
C.D (0.05)	3.50	5.52	9.65	22.35
Iron sulphate levels (S)				
$FeSO_4$ @ 0 kg ha^{-1} (SP_1)	30.94	49.96	72.77	170.8
$FeSO_4$ @ 2.5 kg ha^{-1} (SP_2)	34.33	53.04	79.64	185.9
$FeSO_4$ @ 5 kg ha^{-1} (SP_3)	37.51	58.29	88.13	207.0
$FeSO_4$ @ 7.5 kg ha^{-1} (SP_4)	38.77	60.72	93.00	219.5
S. Em.±	0.78	1.20	2.59	6.09
C.D (0.05)	2.27	3.51	7.56	17.79
Interactions (M×S)				
MP_1SP_1	28.11	45.27	65.66	156.75
MP_1SP_2	28.65	45.54	66.99	160.19
MP_1SP_3	29.25	46.97	68.63	164.24
MP_1SP_4	29.69	47.80	70.44	166.36
MP_2SP_1	30.40	48.65	72.00	169.94
MP_2SP_2	34.22	53.27	80.19	187.87
MP_2SP_3	35.91	54.91	83.30	194.13
MP_2SP_4	37.22	56.28	85.88	199.21
MP_3SP_1	32.04	51.51	75.30	174.59
MP_3SP_2	35.02	53.96	81.31	190.61
MP_3SP_3	40.60	61.90	92.79	214.85
MP_3SP_4	42.27	65.57	96.71	234.83
MP_4SP_1	33.20	54.42	78.11	181.87
MP_4SP_2	39.43	59.39	90.07	204.88
MP_4SP_3	44.27	69.38	107.78	254.85
MP_4SP_4	45.92	73.23	118.95	277.67
S. Em.±	1.56	2.41	5.18	12.19
C.D (0.05)	4.55	7.03	15.11	35.58
Absolute control	14.1	31.3	33.09	109.26
S. Em.±	1.62	2.52	5.12	11.99
C.D (0.05)	4.66	7.25	14.74	34.53

Zinc and Iron content (mg kg^{-1})

Zinc and iron application at different levels showed significant difference in zinc and iron content in grain and straw and the results pertaining to the same are presented in Table 2. The application of zinc sulphate @ 7.5 kg ha^{-1} recorded significantly higher zinc and iron content of 56.23 and 136.1 mg kg^{-1} in grain and 30.15 and 107.79 mg kg^{-1} in straw respectively. Similarly application of iron sulphate @ 7.5 kg ha^{-1} recorded significantly higher zinc and iron content of 55.39 and 132.6 mg kg^{-1} in grain and 29.26 and 105.56 mg kg^{-1} in straw respectively. The combined application of zinc sulphate and iron sulphtae did not show any prominent difference in zinc and iron content in grain straw. This increase in zinc and iron content in grain and straw might be attributed to the balanced application of these micronutrients *viz.*, zinc and iron in chelated form along with other major nutrients. The increase in content of zinc and iron might be due to Soil application of higher level iron significantly increased iron content in straw and grain at harvest (Gohil *et al.*, 2017) [5].

Zinc and Iron uptake (mg kg^{-1})

The application of different levels of zinc sulphate and iron sulphate showed significant differences with respect to uptake of zinc and iron at harvest and the results are presented in Table 3. Among the different $ZnSO_4$ levels significantly highest uptake of zinc and iron was observed in treatment that received $ZnSO_4$ @ 7.5 kg ha^{-1} (40.70 and 98.73 g ha^{-1}, respectively in grain) and (64.11 and 229.82 g ha^{-1}, respectively in straw). Among the different $FeSO_4$ levels significantly highest uptake of zinc and iron was observed in treatment that received $FeSO_4$ @ 7.5 kg ha^{-1} (38.77 and 93.00 g ha^{-1}, respectively in grain) and (60.72 and 219.52 g ha^{-1}, respectively in straw). The uptake of zinc and iron did not differ significantly with application of different combination of $ZnSO_4$ and $FeSO_4$. However the combined application of $ZnSO_4$ and $FeSO_4$ @ 7.5 kg ha^{-1} recorded numerically higher zinc and iron uptake (45.92 and 118.9 g ha^{-1}, respectively in grain) and (73.23 and 277.67 g ha^{-1}, respectively in straw).

The significant increase in the uptake of micronutrients due to application of zinc sulphate alone and iron sulphate alone may be due to the application of these micronutrients to the already deficient soils, and also since these micronutrients were applied after mixing with vermicompost before 15 days of sowing, which resulted in the chelating effect of zinc and iron which formed stable complexes with the organic matter and were readily available to the plants for uptake, hence due to the greater availability of the chelated micronutrients at the right time of crop growth, especially during the reproductive phase like grain filling which enhanced the overall development of the plants owing to the fulfilment of balanced and complete nutrition for the overall development of the minor legumes that are often neglected when it comes to micronutrient management. The heightened uptake of zinc and iron by the crops can be attributed to the synergistic interplay of iron and zinc within the plant, as elucidated by Saini (2012) in their study. This implies that as the quantities of both iron and zinc applied rise, so does the uptake of zinc and iron. The findings of the study are comparable with previous research findings of Divyashree *et al.* (2018), Gupta and Sahu (2012) [8] and Kuldeep (2018) [11].

Conclusion

The application of zinc sulphate @ 7.5 kg ha^{-1} alone and iron sulphate @ 7.5 kg ha^{-1} alone resulted in increased growth parameters, enhanced the yield parameters. Application of zinc sulphate @ 7.5 kg ha^{-1} alone and iron sulphate @ 7.5 kg ha^{-1} showed positive influence on uptake of Zn and iron. Zinc and iron are essential micronutrients for plant growth and development. Correcting deficiencies of these nutrients in the soil can lead to increased crop yields and production. Adding zinc and iron to the soil can increase the nutrient density of the mothbean crop.

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