International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(5): 614-618

https://www.mathsjournal.com
Received: 13-08-2023
Accepted: 20-09-2023

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Influence of zinc and iron application on yield, quality and economics of mothbean in rainfed conditions 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, yield, quality and economics 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, protein and economics 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 yield parameters, quality parameter and economics of mothbean was noted. All the growth yield parameters increased with increase in zinc sulphate and iron sulphate levels.

Keywords: Growth, iron, mothbean, yield, zinc

Introduction
India is the largest producer of pulses in the world. Pulses are 20 to 25 percent protein by weight which is double the protein content of wheat and three times that of rice. Pulses are an important group of crops in India, which is also responsible for yielding large financial gains by amounting to a large part of the exports. Pulses are the major sources of protein in the diet. Of all categories of people, pulses form an integral part of the Indian diet, providing much-needed protein to the carbohydrate-rich diet. 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) [3]. 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) [7].
Micronutrient deficiency is a severe problem in soil and plants worldwide (Imtiaz *et al.*, 2010) [8]. 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. Identifying deficiencies in soil is the first step, and rectifying the micronutrient balance is crucial. Various nutrient management practices come into play, aiding in the restoration of soil equilibrium and the enhancement of micronutrient levels. These practices pave the way for healthier plants and improved agricultural yields. 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, yield quality and economics of mothbean.

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 75^043^1 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 yield attributes were recorded at regular interval of time during the crop growth period. The Nitrogen content in the seed of mothbean was estimated by Kjeldhal distillation method (Tandon, 1998) [20] and the crude protein (%) in seeds was calculated by multiplying the nitrogen content with factor 6.25 as described by AOAC, (1984) and expressed as per cent. The economics of different treatments was worked out in terms of net returns and B: C ratio, on the basis of prevailing market prices for inputs and outputs. 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 analysis and interpretation of data were carried out using the Fischer's method of analysis of variance technique as described by Gomez and Gomez (1984) [6]. The level of significance used in 'F' test was P = 0.05. Critical difference values were calculated wherever the 'F' test was found significant. In case of non-significant effects, values of standard error of mean are presented in tables.

Results and Discussion

Influence of different levels of zinc and iron on yield parameters of mothbean

Effect of zinc sulphate

The results pertaining to yield parameters are presented in Table 1. It was evident from the results that plant height, dry matter accumulation; number of pods per plant and test weight was significantly influenced by the application of zinc sulphate. The application of zinc sulphate @ 7.5 kg ha^{-1} alone, recorded highest plant height of 46.81 cm, dry matter accumulation of 19.33 g $plant^{-1}$), 24.01 number of pods per plant and a test weight (1000 seeds) of 21.42 g. 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. Zinc plays a crucial role in the activation of specific enzymes responsible for regulating cell division and elongation processes. These enzymatic activities are major contributors to the significant increase in plant height observed in French bean growth (Nadergoli *et al.*, 2011) [14]. Similar findings were also reported by Dashadi *et al.*, 2013 [2]. This marked advancement in yield contributing parameters might be due to enhanced growth parameters the enhancement of these yield attributes through soil application of micronutrients is likely linked to the pivotal role of zinc in multiple essential processes. Zinc is instrumental in activating enzymes, maintaining membrane integrity, facilitating chlorophyll synthesis, ensuring stomatal stability, and supporting starch utilization during the early stages of plant growth. These functions contribute to the accumulation of photosynthetic assimilates in grains, resulting in the production of heavier and more robust greengram grains. Similar research findings were recorded by Misal (2018) [13], Gidaganti *et al.* (2019) [5], and Vinodkumar *et al.* (2020) [21] in greengram, Prasad *et al*. (1984) [17].

Effect of iron sulphate

The plant height, dry matter accumulation, number of pods per plant and test weight were significantly influenced due to application of different levels of iron sulphate and the results of the same are presented in Table 1. The application of iron sulphate @ 7.5 kg ha^{-1} recorded higher plant height (45.02 cm), dry matter accumulation (18.79 g $plant^{-1}$), number of pods per plant (23.39) and test weight (21.10 g). This notable increase in plant height and dry matter accumulation with increase in dosage of iron sulphate may be attributed to the fact that iron promotes plant growth and its favourable influence on stimulating enzyme activity, metabolism which in turn increase in protein synthesis and starch accumulation in the beginning of crop growth period. The increased availability of iron to the plant is believed to have potentially stimulated metabolic and enzymatic activities significantly. This stimulation, in turn, contributed to the robust growth of the cowpea crop (Dobariya and Patel, 2021) [4]. The prominent increase in yield contributing parameters may be owed 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 micronutrients throughout the growth period, especially during the reproductive phase which might have contributed in increasing the yield stimulating parameters.

Similar results were also reported by Kuldeep *et al.* (2018) [11] and Pooja and Sarawad (2019) [16] in chickpea

Interaction effect

The combined application of zinc sulphate and iron sulphate did not show any significant difference with respect to plant height, dry matter accumulation, number of pods per plant and test weight (1000 seeds). However, numerically higher values of plant height, dry matter accumulation, number of pods per plant and test weight were recorded with the application of zinc sulphate and iron sulphate @ 7.5 kg ha^{-1} each.

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)
Zinc sulphate levels (MP)				
$ZnSO_4$ @ 0 kg ha^{-1} (MP_1)	32.13	16.49	18.99	18.61
$ZnSO_4$ @ 2.5 kg ha^{-1} (MP_2)	39.72	17.43	21.77	19.84
$ZnSO_4$ @ 5 kg ha^{-1} (MP_3)	42.64	18.29	22.86	20.12
$ZnSO_4$ @ 7.5 kg ha^{-1} (MP_4)	46.81	19.33	24.01	21.42
S. Em.±	1.15	0.54	0.62	0.42
C.D (0.05)	3.99	1.87	2.15	1.47
Iron sulphate levels (SP)				
$FeSO_4$ @ 0 kg ha^{-1} (SP_1)	34.88	16.87	20.02	18.95
$FeSO_4$ @ 2.5 kg ha^{-1} (SP_2)	38.68	17.49	21.58	19.52
$FeSO_4$ @ 5 kg ha^{-1} (SP_3)	42.72	18.37	22.65	20.42
$FeSO_4$ @ 7.5 kg ha^{-1} (SP_4)	45.02	18.79	23.39	21.10
S. Em.±	1.10	0.42	0.48	0.54
C.D (0.05)	3.22	1.23	1.39	1.57
Interactions (MP×SP)				
MP_1SP_1	30.08	16.29	18.54	18.13
MP_1SP_2	31.13	16.37	18.66	18.27
MP_1SP_3	32.77	16.60	18.97	19.00
MP_1SP_4	34.53	16.69	19.82	19.03
MP_2SP_1	35.30	16.70	20.19	19.03
MP_2SP_2	39.29	17.27	21.95	19.46
MP_2SP_3	41.00	17.67	22.27	19.85
MP_2SP_4	43.28	18.08	22.66	21.02
MP_3SP_1	36.00	17.20	20.32	19.20
MP_3SP_2	40.14	17.28	22.17	19.41
MP_3SP_3	46.27	19.10	24.18	20.42
MP_3SP_4	48.15	19.58	24.77	21.44
MP_4SP_1	38.14	17.30	21.03	19.43
MP_4SP_2	44.15	19.07	23.55	20.92
MP_4SP_3	50.82	20.11	25.17	22.41
MP_4SP_4	54.13	20.82	26.30	22.91
S. Em.±	2.21	0.84	0.95	1.08
C.D (0.05)	NS	NS	NS	NS
Absolute control	22.4	13.4	15.7	17.0
S. Em.±	2.18	0.88	0.99	1.01
C.D (0.05)	6.29	2.54	2.85	2.90

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

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Protein content (%)	Net returns (Rs ha^{-1})	B:C ratio
Zinc sulphate levels (MP)					
$ZnSO_4$ @ 0 kg ha^{-1} (MP_1)	571	1764	20.31	25392	1.92
$ZnSO_4$ @ 2.5 kg ha^{-1} (MP_2)	651	1963	21.33	32632	2.18
$ZnSO_4$ @ 5 kg ha^{-1} (MP_3)	684	2030	21.97	35551	2.28
$ZnSO_4$ @ 7.5 kg ha^{-1} (MP_4)	721	2119	22.69	38823	2.40
S. Em.±	15.57	48.61	0.39	1436.09	0.06
C.D (0.05)	53.87	168.22	1.35	4969.53	0.20
Iron sulphate levels (SP)					
$FeSO_4$ @ 0 kg ha^{-1} (SP_1)	602	1840	20.45	28228	2.03
$FeSO_4$ @ 2.5 kg ha^{-1} (SP_2)	648	1947	21.19	32304	2.17
$FeSO_4$ @ 5 kg ha^{-1} (SP_3)	682	2026	22.10	35346	2.27
$FeSO_4$ @ 7.5 kg ha^{-1} (SP_4)	696	2063	22.56	36521	2.31
S. Em.±	15.72	38.61	0.49	1410.68	0.05
C.D (0.05)	45.89	112.70	1.44	4117.48	0.138
Interactions (MP×SP)					
MP_1SP_1	562	1737	20.15	24666	1.90
MP_1SP_2	565	1749	20.21	24911	1.91
MP_1SP_3	575	1776	20.30	25678	1.93
MP_1SP_4	583	1792	20.57	26313	1.95
MP_2SP_1	594	1822	20.26	27516	2.00

MP_2SP_2	654	1972	21.00	32947	2.20
MP_2SP_3	670	2004	21.88	34315	2.24
MP_2SP_4	687	2053	22.19	35750	2.29
MP_3SP_1	616	1869	20.36	29416	2.07
MP_3SP_2	661	1985	21.23	33435	2.21
MP_3SP_3	721	2104	22.90	38798	2.40
MP_3SP_4	741	2163	23.38	40554	2.46
MP_4SP_1	637	1930	21.01	31313	2.13
MP_4SP_2	711	2083	22.31	37923	2.37
MP_4SP_3	763	2220	23.31	42590	2.53
MP_4SP_4	774	2243	24.11	43467	2.55
S. Em.±	31.44	77.22	0.98	2821.36	0.09
C.D (0.05)	NS	NS	NS	8234.96	0.28
Absolute control	320	1390	19.12	10796	1.55
S. Em.±	30.57	94.34	0.93	2751.50	0.10
C.D (0.05)	88.06	271.76	2.67	7926.14	0.28

Influence of different levels of zinc and iron on yield, quality and economics of mothbean

Effect of zinc sulphate

The zinc sulphate application significantly influenced the grain yield, straw yield, protein content and economics of mothbean. Application of zinc sulphate @ 7.5 kg ha^{-1} recorded higher grain yield of 721 kg ha^{-1}, straw yield of 2119 kg ha^{-1}, protein content of 22.69%. A yield increase of 26.25 per cent was seen with application of zinc sulphate @ 7.5 kg ha^{-1} alone over no zinc sulphate application. The increase in the grain yield of mothbean crop is due to application of optimum dose of zinc sulphate after chelation with vermicompost which enhanced the grain yield. 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]. According to Sharma and Abraham (2010) [19] in their research findings highest haulm yield was recorded with application of 15 kg of zinc sulphate per hectare to blackgram which surpassed the control. Increase in protein content may be ascribed to the role of zinc for the synthesis of tryptophan, a key amino acid in the synthesis of the auxin indolacetic acid (IAA). Dobariya and Patel (2021) [4] indicated that the maximum protein content in grain was reported with soil application of 25.0 kg zinc sulphate per ha, which was significantly higher as compared to control. Significantly higher net returns and B: C were obtained with the application of zinc sulphate at 7.5 kg ha^{-1} (38823 Rs ha^{-1} and 2.40 respectively). However lowest was recorded with no application of zinc sulphate fertilizer. Comparable research findings were also reported by Gidaganti *et al.* (2019) [5] and Rajendar *et al.* (2022) [18] in greengram, in cowpea.

Effect of iron sulphate

The iron sulphate application significantly influenced the grain yield, straw yield, protein content and economics of mothbean. Application of iron sulphate @ 7.5 kg ha^{-1} recorded higher grain yield of 696 kg ha^{-1}, straw yield of 2063 kg ha^{-1}, and protein content of 22.56%. A yield increase of 15.5 per cent was seen with application of iron sulphate @ 7.5 kg ha^{-1} alone over no iron sulphate application. This increase in grain and haulm yield of mothbean may be attributed due to enhanced growth and yield related traits (Number of pods, seeds per pod). The enhanced iron accessibility to the plant could have potentially activated several enzymatic and metabolic processes, consequently enhancing the crop's yield. These findings are in confirmation to research findings by Kumar *et al.* (2009) [12] and Khan *et al.* (2014) [9]. The supreme increase in the crude protein content in mothbean grain may be directed towards the critical role played by iron in metabolic processes such as protein synthesis, nitrogen fixation and DNA synthesis through the action of ribonucleotide reductase. The application of iron to the soil might have increased rhizobium bacteria activity that resulted in increased atmospheric nitrogen fixation and hence better utilization nitrogen from the soil by the crop. These findings were also in line with Pooja and Sarawad (2019) [16]. Among the different iron sulphate levels significantly highest net returns and B C ratio was recorded with the application of iron sulphate @ 7.5 kg ha^{-1} (36521 Rs ha^{-1} and 2.31 respectively). This might be due to application of micronutrients which increased the yield and consequently led to increased net returns and B: C ratio. Comparable research findings were also reported by Gidaganti *et al.* (2019) [5].

Interaction effect

The combined application of zinc sulphate and iron sulphate did not show any significant difference with respect to grain yield, straw yield, protein content, net returns and B: C ratio. However, numerically higher values of grain yield, straw yield, protein content, net returns and B:C ratio were recorded with the application of zinc sulphate and iron sulphate @ 7.5 kg ha^{-1} each.

Conclusion

- All the yield parameters increased with increase in zinc sulphate and iron sulphate levels. The application of zinc sulphate @ 7.5 kg ha^{-1} alone and iron sulphate @ 7.5 kg ha^{-1} alone resulted in enhanced yield parameters, yield, protein content and economics of mothbean.
- Zinc and iron play vital roles in a plant's ability to resist stress such as disease, drought, and temperature fluctuations. Applying these micronutrients can help make the mothbean crop more resilient to adverse growing conditions.

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