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Nutrient response and yield of mungbean in response to zinc and iron through agronomic mechanism of biofortification

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Abstract

A field experiment was conducted at College of Agriculture, Agriculture University, Jodhpur in *kharif* season during 2020 and 2021 to study the effect of agronomic biofortification of zinc and iron on yield and nutrient response of mungbean [*Vigna radiata* (L.) Wilczek] varieties. The experiment was laid out in a split plot design, comprised with two varieties namely GM-7 and MH-421 and three treatments of foliar spray of iron (Fe) and urea in main-plots and four treatments included seed inoculation by zinc solubilizing bacteria with soil application of zinc (Zn) in a combinations were assigned to sub-plots. In this way, the experiment had twenty four treatment combinations were replicated thrice. Mung bean variety 'MH-421' had performed prominently with respect to yield and nutrient response. Biofortified treatment of iron with urea spray and zinc significantly higher seed yield, ABR, iron and zinc response were recorded under treatment foliar spray of 0.5% Fe + 2% urea at flower initiation and pod formation stages and seed inoculation with ZSB + soil application of higher dose of zinc sulphate *i.e.* ZSB (SI) + 25 kg $ZnSO_4$/ha, which remained at par with foliar spray of 0.5% Fe + 2% urea at flower initiation stage and ZSB (SI) + 20 kg $ZnSO_4$/ha at 25, 50 DAS and at harvest stage of mungbean, respectively.

Key words: Foliar spray, iron sulphate, zinc sulphate, zinc solubilizing bacteria, yield, ABR

Introduction

In the arid and semi-arid regions of India, mungbean [*Vigna radiata* (L.) Wilczek] is a short durant pulse crop. After chickpea and pigeon pea, mungbean is the third most important legume grown and consumed in India (Samant and Mohanty, 2017). Mungbean is grown on 3.69 million hectares in India, with a total production of 3.16 million tonnes and an average productivity of 567 kg/ha (Anonymous, 2022). Rajasthan held the first position in India, producing 1.32 million tonnes of mung beans on 2.16 million hectares with an average yield of 610 kg/ha (Anonymous, 2022).

More than half of the world's population is affected due to micronutrients deficiency particularly in the developing countries. In particular, zinc (Zn) and iron (Fe) deficiency in human nutrition are wide spread in Asian developing countries including India (Alloway, 2008). Singh and Behera (2011) were analyzed three lakh soil samples across from India and observed that nearly 49 per cent soils were deficient in zinc, 12 per cent in iron, 3 per cent in copper, 5 per cent in manganese, 33 per cent in boron and 13 per cent in molybdenum.

Factually, zinc is one of the eight essential micro-nutrient require for acceleration of growth and reproduction of the plants. Zinc enriched finger proteins are required in signal transduction,

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regulation and transcription of deoxyribonucleic acid (DNA)/ribonucleic acid (RNA) or other proteins in the plant (Graham, 2008). Zinc involved in the root nodulation of plant and enables to the pulse crops to fix inert nitrogen in the root nodule. Zinc deficiency is not only causing low productivity of the crops, but it is also affects the human health. The major six categories of enzymes which play vital role in the human nutrition have contained zinc (Barak and Helmke, 1993). The solubility of zinc in the soil is very low leading to poor uptake resulted into low bioavailability in the plant and has become the major problems across the world (Alloway, 2009). Therefore, seed inoculation and/or soil application of zinc solubilizing bacteria (ZSB) is need of the day to enhance crop production and nutritional quality by improving zinc availability. The zinc solubilizer mainly ZSB produces so many organic acids and dissolved the non-labial forms of zinc cations and acidifying the rhizosphere that alter the soil pH (Glick, 2012 and Alexander, 1997). Other mechanisms possibly involved in zinc solubilization include oxido-reductive system, production of siderophores and proton that make insoluble form of zinc sulphide to the soluble form of zinc sulphate (Saravanan *et al.,* 2011 and Chang *et al*., 2005).

According to Arnon and Stout (1939), iron (Fe) is an essential micronutrient without which life cycle of plants won't be completed. It is actively participated in the chlorophyll synthesis and act as structural component of hemes, hematin and leghaemoglobin involved in the nitrogen fixation in pulses catalysed by an enzyme called 'nitrogenase'. Although, ubiquitous presence of iron in earth's crust, but low solubility makes it lesser availability and finally poor uptake by crops. It play important role in formation of hemoglobin, transport of oxygen, activation and inactivation of various enzymes which performed main function in the human body (Underwood and Suttle, 1999).

Biofortification word derived from Greek language "*bios*" means "*life*" and Latin word "*fortificare*" means "*making strong*". It can be defined as the process of increasing the concentrations of certain micronutrients in edible portions of plants naturally by application of mineral fertilizers *i.e.* agronomic approaches or through conventional breeding approaches. It is the idea to increase nutritional value of micronutrients particularly zinc and iron through agronomic approaches (fertilizer application), which helps to ensure nutrition security by improving the quality of grains in addition to enhancing productivity of crops (Márquez-Quiroz *et al*., 2015 and Meena *et al.,* 2023). Agronomic related approaches have provided compatible and easy solutions to overcome the deficiency of zinc and iron in human body. Soil and foliar application of zinc and iron are major tools of agronomic approaches to provide nourishment to the crops and also increases the accumulation of zinc and iron in the edible part of plants (Cakmak, 2008). However, remobilization and translocation of zinc and iron in the plants are governed by genetic factors. Also, the chemical compatibility of zinc and iron in the tank mixed are a major concerned for their mobility through xylem and phloem tissues of the plant cell (Cakmak *et al.,* 2004). Therefore, the present experiment was conducted to study the effect of agronomic biofortification of zinc and iron on yield and nutrient response of mungbean [*Vigna radiata* (L.) Wilczek] varieties.

Materials and Methods

A field experiment was conducted on mungbean [*Vigna radiata* (L.) at instructional farm of College of Agriculture, Jodhpur (Rajasthan) during *kharif* season of 2020 and 2021. The soil of experimental field was sandy-loam, slightly alkaline in soil reaction (pH 8.0 to 8.2), non-saline in conductivity (EC 0.12 to 0.13d/Sm), low in organic carbon (0.13 to 0.14%) and available nitrogen (174 to 175.8 kg/ha), whereas medium in phosphorus (20.1 to 21.3 kg/ha), and high in available potassium (325 to 329.4 kg/ha). Similarly, the micronutrient analysis of the experimental soil was low in available zinc (0.46 to 0.48 mg/kg) and available iron (3.20 to 3.21 mg/kg). The average bulk density of soil of the experimental field was 1.74 to 1.77 Mg/m^3. It is evident from data that the maximum and minimum temperature during crop growing season ranged between (31.6 to 39.7°C and 20.3 to 32.0°C)and (29.1 to 38.6°C and 23.0 to 31.3°C) during *Kharif* 2020 and 2021, respectively.

The maximum and minimum relative humidity ranged between (46.7 to 91.0 and 17.3 to 78.5)and (35.6 to 89.8 and 11.6 to 31.3) per cent during *Kharif* 2020 and 2021,respectively. The total rainfall received during the crop season 2020 and 2021 were 197.26 and 181.74 mm, respectively. A field experiment was comprised with two varieties namely GM-7 and MH-421 and three treatments of foliar spray of Fe with urea in main-plots (control, 0.5% Fe + 2% urea at flowering initiation and 0.5% Fe + 2% urea at flowering initiation and pod formation stage) and four treatments of seed inoculation with zinc solubilizing bacteria and along with soil application of zinc (Zn) in a combinations (control, ZSB (SI) + 15 Kg $ZnSO_4$/ha, ZSB (SI) + 20 Kg $ZnSO_4$/ha and ZSB (SI) + 25 Kg $ZnSO_4$/ha) were assigned to sub-plots. The experiment had total twenty four treatment combinations and replicated thrice in Split Plot Design. The seed were sown in furrow opened at the depth of about 4-5 cm using seed rate of 15 kg/ha with inter row spacing of 30 cm. The data recorded for yield, nutrient response and other characters were put to statistical analysis in accordance with the analysis of variance for split plot design by Fisher (1925).

Results and Discussion

Effect of varieties

Yield

The results indicated that seed yield significantly influenced by mungbean varieties (Table 1) during both the years as well as pooled data. On pooled basis, variety 'MH-421' (V_2) magnitude of improvement pertained to seed yield was 20.26 per cent over 'GM-7' (V_1) variety. Attainments of particularly higher or lower yield attributing character among the different varieties are the genetically controlled phenomenon (Sadeghipur, 2008). Such variations in yield attributes among the mungbean varieties have also been observed by several research workers (Goswami *et al.,* 2010; Verma *et al.,* 2011; Choudhary *et al.,* 2018 and Singh *et al.* 2023).

B C ratio

Perusal of data exhibited (Table 1) that marked improvement in B: C ratio was obtained due to different varieties. On pooled basis variety 'MH-421' (V_2) had achieved higher profitability level in respect of B: C ratio (3.73) and additional benefit ratio over variety 'GM-7' (1.20) and showed its economic feasibility over variety 'GM-7' (V_1) (3.11) during investigation. Moreover, variety 'MH-421' (V_2) recorded 19.33 per cent higher economic profitability in terms of B: C ratio over 'GM-7' (V_1) during investigation. The higher grain yield was responsible for the corresponding higher B C ratio of these treatments as compared to control. Similar findings of higher net returns were also reported by Praveena *et al.* (2018) and Haider *et al.* (2020).

Nutrient response

It was observed from the data presenting to zinc and iron response in seed of mungbean during each year of study and in pooled analysis (Table 2) revealed that variety 'GM-7' (V_1) recoded higher response of zinc and iron by 8.41 and 11.34 per cent over 'MH-421' (V_2), respectively. The variations in zinc and iron response among the varieties may be due to their genetic variability for this trait. Similar findings of nutrient response were also reported by Debroy *et al*. 2013.

Effect of iron and urea spray

Yield

Foliar spray of iron and urea had marked effect on seed yield of mungbean during both the years of investigation as well as in pooled analysis (Table 1). It was noticed foliar sprayed with 0.5% Fe+ 2% urea at flower initiation and pod formation stage (FeU_2) and 0.5% Fe + 2% urea at flower initiation stages (FeU_1) magnificent increments in seed yield by 28.70 and 39.20 per cent over control (FeU_0), respectively. However, both the treatments (FeU_2 and FeU_1) showed significant relationship with each others during both the years of experimentation. Foliar spray of 0.5%$FeSO_4$increase in grain and straw yield may be attributed to the fact that favourable nutritional environment in rhizosphere and absorption of iron by plant leaves led to increased photosynthetic efficiency and production of assimilates as stated above, might have also favoured efficient partitioning of photosynthates in different vegetative and reproductive structures particularly the seed which is ultimate sink (Guruprasad *et al.*, 2009; Mondal *et al.,* 2011). Urea application as foliar applied at later stages of crop growth might have helped in increasing the efficiency of older nodules (Da Silva *et al.*,1993), thus improving the symbiotic efficiency of plant and ultimately increase-ing the grain yield. Better photosynthetic efficiency with urea application might have helped in easy translocation of carbohydrates to grain, which could also have ultimately resulted in higher grain yield. The similar results have also been reported by Pal *et al*. (2019); Meena *et al.,* 2020.

B C ratio

Results presented in Table 1 revealed that foliar sprayed with 0.5% Fe+ 2% urea at flower initiation and pod formation stage (FeU_2) of fetched higher profitability level in respect of B: C ratio (3.77) and additional benefit ratio over control (1.30) and showed its economic feasibility over rest of the treatments during both the year of experimentation as well as on pooled basis. Moreover, foliar sprayed with fetched B: C ratio to the tune of 5.01 and 30.44 per cent over0.5% Fe + 2% urea at flower initiation stages (FeU_1) and control (FeU_0) during experimentation. The higher grain yield was responsible for the corresponding higher B C ratio of these treatments as compared to control. Similar findings of higher net returns were also reported by Dhaliwal *et al* (2021) and Pal *et al* (2019).

Nutrient response

An inferred of data presented in Table 2 showed marked improvement in zinc and iron response in mungbean due to foliar spray of iron and urea in individual year and on pooled analysis. Mean data of two years revealed that, two time

Table 1. Effect of agronomic biofortification of zinc and iron on yield and additional benefit ratio of mungbean varieties.

Treatments	Seed yield (kg/ha)			B C ratio			Additional benefit ratio over		
	2020	2021	Pooled	2020	2021	Pooled	Variety	Fe control	Zn control
Varieties (V)			-						
V_1: GM-7	894	952	923	3.06	3.16	3.11	1.00	-	-
V_2: MH-421	1078	1142	1110	3.68	3.79	3.73	1.20	-	-
SEm±	11.80	12.77	8.69	-	-	-	-	-	-
CD (P= 0.05)	37.18	40.25	25.65	-	-	-	-	-	-
Iron and Ureaspray (Fe +U)									
F_0: Control	806	852	829	2.86	2.93	2.89	-	1.00	-
F_1: 0.5% Fe + 2% Urea at FI	1035	1099	1067	3.54	3.65	3.59	-	1.24	-
F_2: 0.5% Fe + 2% Urea at FI and PF	1117	1192	1154	3.71	3.84	3.77	-	1.30	-
SEm±	14.45	15.64	10.65	-	-	-	-	-	-
CD (P= 0.05)	45.53	49.29	31.41	-	-	-	-	-	-
Zinc levels (Zn)									
Z_0: Control	785	841	813	2.82	2.93	2.87	-	-	1.00
Z_1: ZSB (SI) + 15 kg ZnSO4 /ha	957	1008	983	3.25	3.33	3.29	-	-	1.14
Z_2: ZSB (SI) + 20 kg ZnSO4 /ha	1092	1159	1126	3.68	3.80	3.74	-	-	1.30
Z_3: ZSB (SI) + 25 kg ZnSO4 /ha	1109	1181	1145	3.72	3.85	3.78	-	-	1.31
SEm±	11.25	12.68	8.48	-	-	-	-	-	-
CD (P= 0.05)	32.28	36.37	23.90	-	-	-	-	-	-
Interaction(V × Fe)									
SEm±	20.43	22.12	15.06	-	-	-	-	-	-
CD (P= 0.05)	64.39	69.71	44.42	-	-	-	-	-	-
Interaction(V × Zn)									
SEm±	15.92	17.93	11.99	-	-	-	-	-	-
CD (P= 0.05)	45.65	51.43	33.80	-	-	-	-	-	-
Interaction(Fe × Zn)									
SEm±	19.49	21.96	7.34	-	-	-	-	-	-
CD (P= 0.05)	55.91	62.99	20.70	-	-	-	-	-	-

foliar spray of 0.5% Fe + 2% urea at flower initiation and pod formation stage (FeU_1) recorded higher zinc and iron response to the tune of 0.88 and 0.66 per cent over the treatment applied with single times foliar spray of 0.5% Fe + 2% urea at flower initiation stage(FeU_1) on pooled analysis basis. The higher Fe response was observed under the treatment of foliar application Fe. From this study it can be concluded that combined application of foliar was more effective in increasing yield and grain Fe content of mungbean. Similar findings of nutrient response were also reported by Debroy *et al*. 2013.

Effect of ZSB and zinc levels

Yield

The results indicated that seed yield of mungbean was significantly affected by seed inoculation with zinc solubilization bacteria and zinc application during 2020 and 2021 of field trial as well as on pooled analysis basis (Table 1). On pooled basis, the magnitudes of increment subjected to grain yield under seed inoculation with ZSB + 25 kg $ZnSO_4$/ha (Zn_3) and ZSB (SI) + application of 20 kg $ZnSO_4$/ha (Zn_2) by 16.48, 40.84 and 14.55, 38.50 per cent over ZSB (SI) + 15 kg $ZnSO_4$/ha (Zn_1) and control (Zn_0), respectively. Positive effect of zinc solubilizing bacteria and zinc application on grain yield may be due to higher carbonic anhydrase activity, which is localized in cytoplasm and chloroplast facilitating the transfer of CO_2or HCO_3^- during CO_2assimilation phase of photosynthesis through increasing the rate of equilibrium between CO_2 andHCO_3^- in solution. On the other hand, SOD helps to scavenge free radicles and protects the photosynthetic apparatus from oxidative damage (Potarzycki and Grzebisz 2009). Enhancement in major yield attributes, resulted in higher grain yield. This result is also in line with findings of Phattarakul *et al.* (2012); Rehman *et al.* 2012; Meena et al., 2021; Ash *et al.*2020; Gahlot *et al.* 2020 and Singh *et al.* 2023.

B C ratio

Results presented in Table 1 revealed that on pooled basis seed inoculation with ZSB + 25 kg $ZnSO_4$/ha (Zn_3) fetched higher profitability level in respect of B: C ratio (3.78) and additional benefit ratio over control (1.30) and showed its economic feasibility over rest of the treatments during the year of investigation. Moreover, seed inoculation with ZSB + 25 kg $ZnSO_4$/ha (Zn_3) fetched B: C ratio to the tune of 1.06, 14.89 and 35.97 per cent over ZSB (SI) + application of 20 kg $ZnSO_4$/ha (Zn_2), ZSB (SI) + 15 kg $ZnSO_4$/ha (Zn_1) and control (Zn_0), respectively on pooled basis. The higher

Table 2. Effect of agronomic biofortification of zinc and iron of mungbean varieties on iron and zinc response.

Treatments	Iron response			Zinc response		
	2020	2021	Pooled	2020	2021	Pooled
Varieties (V)						
V_1: GM-7	0.852	0.837	0.844	0.768	0.778	0.773
V_2: MH-421	0.758	0.759	0.758	0.709	0.717	0.713
SEm±	-	-	-	-	-	-
CD (P= 0.05)	-	-	-	-	-	-
Iron and Ureaspray (Fe +U)						
F_0: Control	0.000	0.000	0.000	0.000	0.000	0.000
F_1: 0.5% Fe + 2% Urea at FI	1.204	1.192	1.198	1.104	1.117	1.110
F_2: 0.5% Fe + 2% Urea at FI and PF	1.211	1.201	1.206	1.111	1.126	1.119
SEm±	-	-	-	-	-	-
CD (P= 0.05)	-	-	-	-	-	-
Zinc levels (Zn)						
Z_0: Control	0.759	0.768	0.764	0.714	0.719	0.716
Z_1: ZSB (SI) + 15 kg ZnSO4 /ha	0.808	0.798	0.803	0.739	0.750	0.745
Z_2: ZSB (SI) + 20 kg ZnSO4 /ha	0.826	0.812	0.819	0.750	0.762	0.756
Z_3: ZSB (SI) + 25 kg ZnSO4 /ha	0.827	0.813	0.820	0.751	0.760	0.755
SEm±	-	-	-	-	-	-
CD (P= 0.05)	-	-	-	-	-	-

grain yield was responsible for the corresponding higher B C ratio of these treatments as compared to control. Similar findings of higher net returns were also reported by Khan and Prakash (2014), Soni and Kushwaha, (2020) and Gahlot *et al.* (2020) in mungbean due to soil application of zinc along with RDF.

Nutrient response

Elucidation of data summarized in Table 2 revealed that zinc and iron response was improved by mungbean varieties due to zinc fertilization and seed inoculation with ZSB either year of study and in pooled analysis.

Mean data of two years revealed that seed inoculation with ZSB + 20 kg $ZnSO_4$/ha (Zn_2) recorded zinc and iron response by 5.58 and 7.32 per cent , while seed inoculation with ZSB + 25 kg $ZnSO_4$/ha (Zn_3) and seed inoculation with ZSB + 15 kg $ZnSO_4$/ha (Zn_1) recoded by 5.44 , 4.05 and 7.19, 5.10 per cent over control on pooled basis. Similar findings of nutrient response were also reported by Debroy *et al*. 2013.

Conclusion

Based on pooled analysis of two years experimental results, it may concluded that growing of mungbean variety 'MH-421' significantly higher seed yield resulted in prominent improvement in B C ratio as compare to variety 'GM-7'. Among agronomic biofortification treatments, two times foliar spray of 0.5% Fe + 2% urea at flower initiation and pod formation stages and seed inoculation with ZSB and soil application of higher dose of zinc sulphate *i.e.*ZSB (SI) + 25 kg $ZnSO_4$/ha in mungbean gave significantly higher seed yield resulted in improved economic viability and feasibility as B C ratio.

References

Alexander, M. 1997. *Introduction to Soil Microbiology*. New York, NY: John Wiley and Sons.

Alloway, B.J. 2008. *Zinc in soils and crop nutrition*, 2nd edition, IZA Publications, International Zinc Association Brussels, Belgium and International Fertilizer Association Paris, France. pp. 139.

Alloway, B.J. 2009. Soil factors associate with zinc deficiency in crops and humans. *Environmental Geochemistry and Health,* **31**(5):537-548.

Anonymous, 2022. Agricultural Statistics at a Glance 2022. Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics, pp. 125-126.

Arnon, D.I. and Stout, P.P. 1939. The essentiality of certain elements in minute quantity for plants with special reference to copper. *Plant Physiology,* **14**: 1460–1470.

Ash M Yadav J and Yadav J S, 2020. Yield attributes of rice (*Oryza sativa*) as affected by integrated use of zinc oxide and zinc solubilizers. *Indian Journal of Agricultural Sciences,* **90**(11): 2180-2184.

Barak, P. and Helmke, P. A. 1993. The chemistry of zinc. Proceedings of International Symposium on Zinc in Soil and Plants, pp. 1-13.

Cakmak, I. 2008. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification. *Plant Soil,* **302**: 1-17.

Cakmak I, Torun A, Ozkan H, Millet E, Feldman M, Fahima T, Korol A B, Nevo E and Braun h, 2004. *Triticum dicoccoides:* an important genetic resource for increasing zinc and iron concentration in modern cultivation wheat. *Journal of Soil Science and Plant Nutrition,* **50**: 1047-1054.

Chang H B, Lin C W, and Huang H J, 2005. Zinc induced cell death in rice (*Oryza sativa* L.) roots. *Plant Growth Regulator,* **46**: 261–266.

Choudhary H, Yadav L R, Yadav M R, Kantwa R and Kumawat R, 2018. Growth and productivity of mungbean verities under foliar application of iron in semi-arid eastern plain zone of Rajasthan. *International Journal of Chemical Studies,* **6**(5): 2269-2274.

Da Silva P M, S M Tsai and R Bonetti, 1993. Response to inoculation and N fertilization for increased yield and biological nitrogen fixation of common bean (*Phaseolus vulgaris* L.). *Plant and Soil* 152:123–30. doi:10.1007/ BF00016341.

Debroy, P Narwal, R P Malik, R S and Narender. 2013. Enrichment of greengram (Vigna radiata) genotypes with iron through ferti-fortification. *Indian Journal of Agricultural Sciences*, **83**(10):1095–8.

Dhaliwal S S, Sharma V, Shukla A K, Verma V, Behera

S K, Singh P, Alotaibi S S, Gaber A and Hossain A, 2021. Comparative Efficiency of Mineral, Chelated and Nano Forms of Zinc and Iron for Improvement of Zinc and Iron in Chickpea (*Cicer arietinum* L.) through Biofortification. *Agronomy*, **11**(12): 2436.

Fisher, R.A. 1925. Statistical Methods for Research Workers. Edinburgh: Oliver and Boyd.

Gahlot N, Ram M, Parewa H P, Meena R and Sarita, 2020. Enhancing mungbean productivity and profitability through zinc and iron application in western Rajasthan. *International Journal of Bio-resource and Stress Management*, **11**(2): 178-182.

Glick B K, 2012. *Plant growth-promoting bacteria: Mechanisms and applications.* Hindawri Publishing Corporation Scientifica, **5**: 15.

Goswami K R, Choudhary H, Sharma M K, Sharma D and Bhuyan J, 2010. Evaluation of greengram genotypes for morphological, physiological traits and seed yield. *Annals Plant of Physiology*, **24**(2): 115-120.

Graham R D, 2008. Micronutrient deficiencies in crops and their global significance. Micronutrient Deficiencies in Global Crop Production, pp. 41-61.

Guruprasad B P, Kurigod V and Hundekar S T, 2009. Influence of methods of iron sulphate application on yield and nutrient uptake by groundnut (*Arachis hypogaea* L.) genotypes on calcareous soils. *Karnataka Journal of Agricultural Science*, **22**(5): 1104-1106.

Haider M U, Hussain M, Farooq M and Nawaz A, 2020. Optimizing zinc seed priming for improving the growth, yield and grain biofortification of mungbean (*Vigna radiata* (L.) Wilczek). *Journal of Plant Nutrition*, **43**(10):1438-1446.

Marquez-Quiroz C, De-la-Cruz-Lázaro E, Osorio-Osorio R and Sánchez-Chávez E, 2015. Biofortification of cowpea beans with iron: influence on mineral content and yield. *Journal of Soil Science and Plant Nutrition*, **15**(4): 839-847.

Meena S N, Jadon C, Meena L K, Meena B S, Yadav R K and Singh P, 2021. Impact of gibberellic acid on growth, yield and economics of pigeonpea [*Cajanus cajan* (L.)]. *Indian Journal of Agriculture and Allied Sciences*, **7**(2): 65-69.

Meena S N, Patidar B K, Jadon C, Meena H P, Meena B S, Yadav R K, Yadav S L, Meena N L, Singh P and Jat M L, 2020. Response of Pigeonpea [(*Cajanus cajan* (L.)] to Foliar Application of Nutrient and Pest Management at Flowering Stage. *International Journal of Bio-resource and Stress Management*, **11**(5) 432-436. DOI: HTTPS://DOI.ORG/10.23910/1.2020.2126b

Meena S N, Singh P, Meena L K, Yadav S L, Dhakad U, Regar S N and Meena B S, 2023. Effect of plant growth regulators in conjunction with insecticides on the productivity of pigeon pea [*Cajanus cajan* (L.) Millsp.]. *Environment and Ecology*, **41**(1B): 480-485.

Mondal M M A, Rahman M A, Akhter M B and Fakivz M S A, 2011. Effect of foliar application of nitrogen and micronutrient on growth and yield in mungbean. *Legume Research*, **34**(3): 166-171.

Pal V, Singh G and Dhaliwal S S, 2019. Agronomic biofortification of chickpea with zinc and iron through application of zinc and urea. *Journal Communications in Soil Science and Plant Analysis*, **50**(15): 1864-1877.

Phattarakul N, Rerkasem B, Li L J, Wu L H, Zou C Q, Ram H and Yazici A, 2012. Biofortification of rice grain with zinc through zinc fertilization in different countries. *Plant and Soil*, **361**(1-2): 131-141.

Potarzycki, J. and Grzebisz, W, 2009. Effect of zinc foliar application on grain yield of maize and its yielding component. *Plant Soil and Environment*, **55**(12): 519-527.

Praveena R, Ghosh G and Singh, V. 2018. Effect of Foliar Spray of Boron and Different Zinc Levels on Growth and Yield of Kharif Greengram (*Vigna radiata*). *International Journal of Current Microbiology and Applied Sciences*, **7**(8): 1422-1428.

Rehman H U, Aziz T and Farooq M, 2012. Zinc nutrition in rice production systems: A review. *Plant Soil* **361**(1-2): 203–226. doi: 10.1007/s11104-012-1346-9.

Sadeghipur O, 2008. Response of mungbean varieties to different sowing dates. *Pakistan Journal of Bio Sciences*, **11**(6): 2048-2050.

Samant T K and Mohanty T R, 2017. Effect of sowing date and weed management on productivity and economics of rainfed mungbean (*Vigna radiata*). *Indian Journal of Agronomy*, **62**(3): 332-337.

Saravanan V S, Kumar M R and Sa T, 2011. Microbial zinc solublization and their role on plants.*Bacteria in agrobiology: Plant nutrient management edition* **1**, pp. 47-63.

Singh M V and Behera S K, 2011. AIRCP on micro and secondary nutrients and pollutant elements in soil and plants- A Profile. *Research Bulletin,* **10**: 1-57.

Singh U, Dey P, Singh L N, Ram M and Choudhary R, 2023. Improved varietal selection and optimum soil application of Zn enhance mungbean (*Vigna radiata* L. Wilczek) productivity and profitability. *Annals of Agriculture Resrerch New Series,* **44**(1): 83-87.

Underwood E J and Suttle N F, 1999. *The mineral nutrition of Livestock*, 3rd edition, CABI International Publishing, Wallingford Oxon. 614p.

Verma C K, Yadav D and Singh V, 2011. Effect of yield and quality of green gram varieties by foliar spray of urea and seed rate. *Plant Archives* 11(1): 289-291.