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Impact of Foliar application of Micronutrients on growth and yield of Cowpea (*Vigna unguiculata* L.)

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Abstract
The "Impact of Foliar application of Micronutrients on Growth, Yield and Quality of Cowpea [*Vigna unguiculata* L.]" was the subject of a field experiment carried out in the *kharif* season of 2023 at the Research Farm, School of Agriculture, Suresh Gyan Vihar University Jaipur. With three replications, the experiment was set up in a randomized block design. Ten treatments made up the experiment *viz*., $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) (T_2), $ZnSO_4$ (0.5%) + $FeSO_4$ (1.0%) (T_3), $ZnSO_4$ (0.5%) + $FeSO_4$ (1.5%) (T_4), $ZnSO_4$ (1.0%) + $FeSO_4$ (0.5%) (T_5), $ZnSO_4$ (1.0%) + $FeSO_4$ (1.0%) (T_6), $ZnSO_4$ (1.0%) + $FeSO_4$ (1.5%) (T_7), $ZnSO_4$ (1.5%) + $FeSO_4$ (0.5%) (T_8), $ZnSO_4$ (1.5%) + $FeSO_4$ (1.0%) (T_9) and $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}), including the control (T_1). CPD-119 was the cowpea cultivar used in the research. As demonstrated by the experimental results, foliar application of $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}) resulted in significantly higher growth parameters, including plant height, number of branches, number of green leaves, number of nodules, and accumulation of dry matter at different growth stages; however, it was still on par with the other treatments in terms of yield attributes and yield, including number of pods plant^{-1}, number of seeds pod^{-1}, seed yield, straw yield and biological yield. The foliar application of micronutrients did not significantly affect the cowpea test weight and harvest index.

Keywords: Accumulation, parameters, matter

Introduction
Often referred to as "poor man's meat," pulses are the main sources of protein for a sizable portion of the global vegetarian population. Pulses typically have between 20 and 30 per cent protein. Infect, for the previous 20 years, pulse productivity and production have stagnated. Due to the "Green Revolution" brought about by high-yielding cereal types, there has been a shift of agricultural land from pulses to cereals. This is mostly because pulses have an unstable low yield potential. Chickpea, pigeonpea, cowpea, greengram, blackgram, lentil, and pea are among the major pulse crops cultivated in India. In India, 23.02 million tonnes of pulses are produced on an area of 29.36 lakh hectares (Anonymous, 2019-20) [3].
India grows cowpea (*Vigna unguiculata* L. walp), a significant *kharif* pulse crop, for its edible pods, grain, fodder, and green manure. Cowpeas are cultivated for their edible pods as well as their dry seeds, which are used as a pulse in cooking. The vegetable cowpea is among the oldest crops that humans have ever grown. It is a widely cultivated, well-liked vegetable worldwide. This warm-season crop is widely adapted to humid tropical and subtropical regions. It is commonly farmed all year round in India. Cowpeas have long been grown in combination with a variety of other crops, including millets, sorghum, and maize. It can be used in a variety of ways, such as using young, green seedlings as vegetables or as cattle fodder. Green pods can also be used as vegetables for human consumption. It is an excellent source of protein (20–25%). By fixing nitrogen in the soil (60–70 kg N ha^{-1}) in collaboration with symbiotic bacteria in favourable conditions for N fixation, cowpeas also improve soil fertility. However, they require an initial dose of nitrogen for early development and establishment (Russell, 1961). Cowpeas are grown on 0.50 lakh hectares of land in Rajasthan, where they produce 0.33 lakh tonnes of product annually on average (653 kg ha^{-1}) (Anonymous, 2020) [4].
Fe, Zn, B, Cu, Mn, and Mo are the micronutrients that pulse crops absolutely require.

Ni and Co are two additional mineral nutrients that, in small amounts, are thought to be necessary for the growth of some plants. Due to intensive cropping, erosion-induced topsoil loss, micronutrient leaching, liming of acid soils, lower proportions of farmyard manure compared to chemical fertilisers, higher purity of chemical fertilisers, and the use of marginal lands for crop production, the incidence of micronutrient deficiencies in crops has significantly increased in recent years.

Zinc is one of the micronutrients that is necessary for the activity of multiple enzymes, including RNA polymerase, carbonic anhydrase, alcohol dehydrogenase, and superoxide dismutase. Zinc is also involved in the metabolism of nitrogen. Through nodule formation, zinc is known to play a role in nitrogen fixation. Additionally, it is essential for the oxidation processes that occur in plant cells, aids in the transformation of carbohydrates, and controls plant sugar (Verma *et al*., 2004) [24]. Iron, along with zinc, is essential for plants to maintain chlorophyll and is a component of various enzymes, including ferrodoxin, hemoglobin and catalase, *etc*. In biological oxidation and reduction as well as other metabolic processes in plants, such as oxidative photophosphorylation during cell respiration, it serves as a catalyst. Furthermore, iron may also be connected to the metabolism of organic acids, such as ascorbic acid, mallic acid, and citric acid (Tandon, 2009) [22].

It has been suggested that foliar spraying various micronutrients is as efficient as soil treatment in addressing the issue of micronutrient deficiencies in subsurface soil (Torun *et al*., 2001) [23]. The benefits of foliar application include controlling plant nutrient uptake, eliminating losses from leaching and fixing, and facilitating the rapid and efficient utilisation of nutrients (Manonmani and Srimathi, 2009) [12]. A temporary solution for achieving nutritional effectiveness and increasing output in soils with deficiencies is foliar spraying. One effective and affordable way to meet the crop's nutritional needs is to apply nutrients foliarly in order to maximise and utilise its genetic potential. One potential strategy to increase the productivity of pulses, such as gramme, is to apply nutrients foliarly using water soluble fertilisers (Rajeshwari, 2011) [17]. Plant performance, yield, and yield characteristics are enhanced by foliar Zn application during the blooming stage (Pandey *et al*., 2013) [16].

Materials and Methods

The experiment was set up at the Suresh Gyan Vihar University's Research Farm, School of Agriculture, in Jaipur, Rajasthan. The location of the experiment is 432 meters above mean sea level, with 26º48'35" N latitude and 75º51'44" E longitude. This area is located in Rajasthan's Semi-Arid Eastern Plain Zone, or Agroclimatic Zone IIIa. This tract receives 400–500 mm of rainfall on average every year, with the majority coming from the south-west monsoon in July and August. The winter months saw very little rain. During the crop season, the highest and lowest temperatures were, respectively, 30.2 °C to 35.2 °C and 9.9 °C to 23.0 °C. During the crop season, 365.5 mm of rainfall were recorded.

The experimental field soil of sandy loam texture had a pH of 8.5, slightly alkaline in reaction, very low available nitrogen, medium available phosphorus, high available potassium, low available sulphur. The CPD-119 type of crop was seeded on July 25, 2023. There were three replications and ten treatments *viz*., control (T_1), $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) (T_2), $ZnSO_4$ (0.5%) + $FeSO_4$ (1.0%) (T_3), $ZnSO_4$ (0.5%) + $FeSO_4$ (1.5%) (T_4), $ZnSO_4$ (1.0%) + $FeSO_4$ (0.5%) (T_5), $ZnSO_4$ (1.0%) + $FeSO_4$ (1.0%) (T_6), $ZnSO_4$ (1.0%) + $FeSO_4$ (1.5%) (T_7), $ZnSO_4$ (1.5%) + $FeSO_4$ (0.5%) (T_8), $ZnSO_4$ (1.5%) + $FeSO_4$ (1.0%) (T_9) and $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}), which were laid out in randomized block design.

Five plants were selected randomly from each plot and tagged permanently. Height of these five plants was measured at 30, 50 DAS and at harvest from the base of the plant to the top of the main shoot by metre scale and their mean was expressed as plant height (cm). The number of branches produced plant^{-1} counted at 30, 50 DAS and at harvest of five randomly tagged plants in all the treatments. The mean of five plants were recorded as the number of branches plant^{-1}. The number of green leaves plant^{-1} counted at 30, 50 DAS and at harvest stage of five randomly tagged plants in all the treatments. The mean of five plants were recorded as the number of green leaves plant^{-1}. The plants were uprooted randomly at flowering. The uprooted plant was washed with clean tap water for recording number of active nodules. Dry matter accumulation (g plant^{-1}) was recorded at 30, 50 DAS and at harvest and plants were uprooted randomly from sample rows of each plot. After removal of the root portion, the samples were first air-dried for some days and finally dried in an electric oven at 68 °C till a constant weight was achieved. The weight was recorded and expressed as g plant^{-1}.

The pods of five plants randomly selected from each plot were counted at harvest and average number of pods plant^{-1} was worked out. Number of seeds pod^{-1} was recorded at harvest by counting the seeds of the five randomly collected pods from each plot and the average value was estimated. Samples were drawn randomly from produce of each plot and one hundard seeds were counted from each sample and weighed to record seed index (g). After threshing and winnowing of the seeds from each net plot were weighed in kg plot^{-1} and converted in kg ha^{-1} for seed yield. Haulm yield was obtained by subtracting the seed yield (kg ha^{-1}) from biological yield (kg ha^{-1}). At maturity completely, dried biomass *i.e*. pods and straw from each net plot harvested were weighed and computed for biological yield as kg ha^{-1}. The harvest index was calculated by using following formula and expressed as percentage (Singh and Stoskoff, 1971).

$$\text{HI (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Fisher, 1950) [6].

Results and Discussion

Growth parameters

At all phases of plant growth, foliar application of $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}) resulted in a significant improvement in plant height, branch count, number of green leaves, and dry matter production (Table 1 and 2). The foliar application of $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}) may have increased growth characteristics because the plant has enough zinc available, which may have an enhanced catalytic or stimulatory effect on the majority of the physiological and metabolic processes of the plant. Zinc deficiency causes a drop in auxin content and plays a significant role in controlling the concentration of auxin in plants, regardless of its impact on growth. Zinc also increases the cation exchange capacity of roots, which improves the absorption of vital nutrients. The use of different $FeSO_4$ treatments increases the number of branches per plant, plant height, number of green leaves per plant, and production of dry matter. Similar findings demonstrated that cowpea plant increases in vegetative development were reflected by foliar fertilisation with Zn and Fe (Ali *et al*., 2014 and Mona and Azab, 2016) [1].

In addition to providing better nutrition over a longer period of time and having a synergistic effect of both nutrients on the yield component (Gaffar *et al*., 2011) [7], the addition of zinc and ferrous has also caused a higher activation of micronutrients, primarily because of its beneficial effects in mobilising the native nutrients to increase their availability (Meena *et al*., 2006) [14]. Comparable outcomes were also noted when zinc was applied topically to fenugreek by Meena (2002) [13], mungbean by Sammauria (2007) [19], and fenugreek by Mondal *et al.* (2012). According to Amirani and Kasraei (2015) [2], the growth characters may have grown as a result of the foliar application of micro components.

Yield attributes and yield

Data (Tables 3) show that foliar micronutrient administration led to a considerable increase in pods plant^{-1}, seeds pod^{-1}, seed, haulm and biological yield. Under foliar application of $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}), the highest pods plant^{-1}, seeds pod^{-1}, test weight, seed, haulm and biological yield were observed. More micronutrients applied by foliar spray demonstrated increased effectiveness. As previously mentioned, a primary determinant for improving mature qualities appears to be a notable improvement in a variety of vegetative attributes as well as overall effective vegetative development performance under adequate nutrient supply. The shape of the reproductive organs is greatly influenced by the fundamental vegetative phase, which is crucial for achieving a high yield. A favourable association between the number of branches and pods has been observed in several studies. Its pre-assimilated content determines how nutrients are mobilized from vegetative parts to developing pods and seeds. Plants are predicted to use nutrients more efficiently when there is an adequate supply available, as this investigation's findings about increased dry matter buildup demonstrate. Furthermore, more effective nutrition mobilisation to reproductive traits is certain to happen in the presence of sufficient nutrients. Plant^{-1} improved pod and seed production could be attributed to this occurrence.

When there was a sufficient supply of nutrients, seed yield rose dramatically. It was unavoidably noted in the majority of the research that the relationship between seed output and pod count and seed pod^{-1}. $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%) (T_{10}) applied foliarly resulted in a significant increase in the number of pods plant^{-1}, seeds pod^{-1}, seed yield, stover yield, and biological yield. Zinc's involvement in the biosynthesis of indole acetic acid (IAA) and, in particular, in the initiation of primordia for reproductive parts and the partitioning of photosynthates towards them (Wear and Hagler, 1968) [25] may have contributed to the increase in yield attributes. This could have led to improved flowering and fruiting. Habib (2012) [8] also discovered a favourable link between grain yield and accessible soil Zn and Fe. Branching, blooming, and yield components such as number of pod-bearing branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, and seed yield are all increased by the application of $FeSO_4$. Similar findings demonstrated that applying Fe and Zn fertiliser topically to cowpea plants increased the yield component (Ali *et al*., 2014 and Mona and Azab, 2016) [1, 15].

The positive impact of these nutrients on metabolism and biological activity, as well as their stimulatory effect on photosynthetic pigments and enzymatic activity, may also be responsible for this enhancing effect, which increases yield qualities (Thalooth *et al*., 2006). Enhanced carbohydrate synthesis could potentially be a consequence of the increased iron availability. Sharma (2006) [21] found comparable results with fenugreek, and Kumawat *et al.* (2006) [11] found similar results with mungbean. Moreover, Kumar *et al.* (2002) [10] in mungbean, Sammauria (2007) [19] in fenugreek, Sharangi *et al.* (2009) [20] in fennel and Chhiba *et al.* (2007) in methi and combined application by Kalidasu *et al.* (2008) [9] in coriander, Ravi *et al.* (2008) [18] and Habib (2012) [8] in wheat reported an increase in yield attributes and yield with foliar application of zinc sulphate.

Table 1: Plant height and dry matter accumulation of cowpea as influenced by foliar application of micronutrients at periodic intervals

Treatments	Plant height (cm)			Dry matter accumulation (g plant^{-1})		
	30 DAS	50 DAS	At harvest	30 DAS	50 DAS	At harvest
T_1: Control	26.95	67.68	64.77	12.37	23.94	38.33
T_2: $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%)	32.10	78.99	76.08	14.74	27.94	44.74
T_3: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.0%)	32.58	79.80	76.89	14.96	28.23	45.20
T_4: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.5%)	32.26	79.98	77.08	14.81	28.30	45.31
T_5: $ZnSO_4$ (1.0%) + $FeSO_4$ (0.5%)	32.78	80.89	77.98	15.04	28.62	45.82
T_6: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.0%)	32.72	80.94	78.03	15.02	28.63	45.85
T_7: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.5%)	32.13	81.24	78.33	14.75	28.74	46.02
T_8: $ZnSO_4$ (1.5%) + $FeSO_4$ (0.5%)	32.24	81.51	78.61	14.80	28.84	46.17
T_9: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.0%)	32.72	81.81	78.91	15.05	28.94	46.34
T_{10}: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%)	32.78	81.92	79.02	15.07	28.98	46.41
SEm±	0.29	1.66	1.64	0.13	0.92	1.20
LSD (*P = 0.05*)	0.87	4.94	4.86	0.40	2.75	3.56

Table 2: Number of branches plant^{-1}, number of green leaves plant^{-1} and number of active nodules at flowering of cowpea as influenced by foliar application of micronutrients at periodic intervals

Treatments	Number of branches plant^{-1}			Number of green leaves plant^{-1}			Number of active nodules at flowering
	30 DAS	50 DAS	At harvest	30 DAS	50 DAS	At harvest	
T_1: Control	3.22	4.82	6.37	22.13	46.36	40.75	20.79
T_2: $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%)	3.62	5.63	7.44	24.92	54.95	48.30	24.64
T_3: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.0%)	3.62	5.69	7.51	24.91	55.56	48.84	24.91
T_4: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.5%)	3.58	5.70	7.53	24.66	55.70	48.96	24.98
T_5: $ZnSO_4$ (1.0%) + $FeSO_4$ (0.5%)	3.64	5.76	7.62	25.06	56.39	49.57	25.29
T_6: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.0%)	3.64	5.77	7.62	25.01	56.42	49.60	25.30
T_7: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.5%)	3.57	5.79	7.65	24.56	56.65	49.80	25.40
T_8: $ZnSO_4$ (1.5%) + $FeSO_4$ (0.5%)	3.55	5.81	7.68	24.42	56.86	49.98	25.50
T_9: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.0%)	3.64	5.83	7.70	25.06	57.09	50.18	25.60
T_{10}: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%)	3.66	5.84	7.71	25.09	57.17	50.26	25.64
SEm±	0.03	0.07	0.38	0.22	1.36	1.27	0.87
LSD ($P = 0.05$)	0.10	0.23	1.17	0.66	4.05	3.76	2.58

Table 3: Yield attributes, yield and harvest index of cowpea as influenced by foliar application of micronutrients

Treatments	Yield attributes			Yield (kg ha^{-1})			Harvest index (%)
	Number of pods plant^{-1}	Number of seeds pod^{-1}	Seed index (g)	Grain	Stover	Biological	
T_1: Control	5.71	4.73	150.62	654.12	1445.59	2099.71	31.15
T_2: $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%)	7.24	6.67	150.74	708.39	1523.05	2231.44	31.75
T_3: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.0%)	7.44	6.93	150.89	716.21	1528.39	2244.59	31.91
T_4: $ZnSO_4$ (0.5%) + $FeSO_4$ (1.5%)	7.64	7.18	160.03	723.48	1535.95	2259.43	32.02
T_5: $ZnSO_4$ (1.0%) + $FeSO_4$ (0.5%)	7.79	7.38	160.24	734.76	1535.64	2270.40	32.36
T_6: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.0%)	7.92	7.54	160.38	765.98	1570.27	2336.25	32.79
T_7: $ZnSO_4$ (1.0%) + $FeSO_4$ (1.5%)	8.01	7.65	160.52	797.67	1603.31	2400.98	33.22
T_8: $ZnSO_4$ (1.5%) + $FeSO_4$ (0.5%)	8.16	7.84	160.62	826.97	1653.11	2480.08	33.34
T_9: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.0%)	8.25	7.96	160.87	863.86	1725.12	2588.98	33.37
T_{10}: $ZnSO_4$ (1.5%) + $FeSO_4$ (1.5%)	8.38	8.12	160.92	914.79	1817.68	2732.47	33.48
SEm±	0.46	0.45	7.00	11.63	24.49	35.23	0.94
LSD ($P = 0.05$)	1.38	1.35	NS	34.54	72.77	104.67	NS

Conclusion

Micronutrients like zinc and iron are crucial for optimal plant growth and yield, especially in the face of rising deficiencies due to modern agricultural practices. Their roles in enzymatic activities, nitrogen fixation, and chlorophyll maintenance underscore their importance. Foliar application of these nutrients has proven effective in mitigating deficiencies and enhancing plant performance, as demonstrated by significant improvements in growth parameters and yield attributes. This method not only increases nutrient uptake efficiency but also supports higher productivity in crops, offering a practical solution for enhancing agricultural output in nutrient-deficient soils.

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