"Effect of Agronomic fortification of pigeonpea with Zn and Fe on growth and yield parameter and yield of pigeonpea''

ABSTRACT

Pigeonpea (*Cajanus cajan*) is a major leguminous crop providing substantial nutritional benefits, especially protein to millions of people worldwide. However, its yield and nutritional quality are often constrained by micronutrient deficiencies, particularly zinc (Zn) and iron (Fe). This study investigates the effects of agronomic fortification with Zn and Fe on the growth, yield parameters and overall yield of pigeonpea. The experiment was conducted through a randomized complete block design with nine treatments and replicated thrice. Agronomic fortification involved foliar application of Zn and Fe at flowering and pod development stages. Results indicated that among different treatments the combined foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flowerand pod initiation recorded significantly higher plant height (156.7 cm), number of branches per plant (16.8),number of pods per plant (98.5), number of seeds per pod (5.4), pod weight per plant (128.5 g), seed weight per plant (83.5 g), seed yield (1056 kg ha^{-1})and stalk yield (2503 kg ha^{-1}) in the fortified treatments compared to the control. Notably, the combined Zn-Fe fortification exhibited the most pronounced effects on growth and yield parameters. Overall, agronomic fortification with Zn and Fe positively influenced the growth, yield parameters and yield of pigeonpea, suggesting its potential as a sustainable strategy to alleviate micronutrient deficiencies and enhance crop productivity in pigeonpea cultivation systems.

Keywords: Pigeonpea, Fortification, Zinc, Iron, Micronutrients, Growth, Yield.

INTRODUCTION

Pigeonpea (*Cajanus cajan*) is an important legume crop cultivated in many tropical and subtropical regions, primarily for its high protein content and ability to fix atmospheric nitrogen, which enhances soil fertility. However, pigeonpea often suffers from mineral nutrient deficiencies, particularly zinc (Zn) and iron (Fe), which are essential for plant growth, development, and overall yield. Zinc and iron deficiencies in pigeonpea can lead to stunted growth, reduced yield, and lower nutritional quality, posing significant challenges to food security and economic prosperity in regions reliant on this crop.

Zinc (Zn) plays a crucial role in both plant physiology and human nutrition. In plants, zinc is an essential micronutrient involved in various biochemical and physiological processes, including enzyme activation, protein synthesis, photosynthesis, and hormone regulation. Zinc deficiency in plants can lead to stunted growth, reduced yield, and susceptibility to diseases. Moreover, zinc is also important for human health, where it functions as a cofactor for numerous enzymes involved in metabolism, immune function and DNA synthesis. Zinc deficiency in humans can result in impaired growth and development, weakened immune system or increased susceptibility to infections. Therefore, ensuring an adequate supply of zinc in both plant nutrition and human diets is crucial for sustainable agriculture and human health (Cakmak,2008).

Iron (Fe) is an essential micronutrient critical for both plant growth and human health. In plants, iron plays a key role in photosynthesis, respiration, DNA synthesis, and nitrogen fixation. Iron deficiency in plants can result in chlorosis, reduced growth, and decreased yield. In human nutrition, iron is vital for oxygen transport as a component of heamoglobin in red blood cells and as a cofactor for various enzymes involved in energy metabolism. Iron deficiency in humans leads to anemia, fatigue, impaired cognitive function, and compromised immune response. Therefore, ensuring adequate iron availability in soil for plants and in diets for humans is crucial for sustainable agriculture and human well-being (Briat*et al*., 2015).

Agronomic biofortification of zinc (Zn) and iron (Fe) in pigeonpea (*Cajanus cajan*) involves targeted nutrient management strategies to enhance the levels of these essential micronutrients in the edible parts of the crop. Pigeonpea, being a valuable legume crop rich in protein and important nutrients, can benefit significantly from biofortification practices to improve its nutritional value(Media*et al*., 2012). Studies have shown that optimizing soil nutrient availability through fertilization techniques can increase the uptake and accumulation of Zn and Fe in pigeonpea plants, leading to enhanced levels of these micronutrients in seeds of pigeonpea (Kumar*et al*.,2020).Agronomic biofortification not only contributes to addressing Zn and Fe deficiencies in soils but also offers a sustainable solution to improve the dietary intake of these vital nutrients, especially in regions where pigeonpea is a dietary staple. Research efforts focusing on agronomic biofortification in pigeonpea hold promise for enhancing food and nutritional security, particularly in populations reliant on pigeonpea-based diets.

MATERIAL AND METHODS

The field experiment took place during the *Kharif* season of 2023 in red sandy loam soil at the Zonal Agricultural Research Station, Gandhi Krishi Vigyana Kendra, University of Agricultural Sciences, Bangalore. This research site located in the Eastern Dry Zone (Zone-V) of Karnataka, known for its characteristic red soils and primarily rainfed ecosystem. Initially, the soil pH measured 6.3, with an electrical conductivity of 0.16 dS m^{-1}. The organic carbon content was found to be 0.43 per cent, indicating a moderate level. The soil found to have exhibited medium levels of available nutrients, with nitrogen at 285.4 kg ha^{-1}, phosphorus at 38.2 kg ha^{-1} and potassium at 258.2 kg ha^{-1}.The field experiment was laid out in Randomized complete block design (RCBD) replicated thrice with 9 treatments *viz*., T_1: RDF (Absolute control); T_2: Foliar application of 0.5 % $ZnSO_4$ at flower initiation; T_3: Foliar application of 0.5 % $FeSO_4$ at flower initiation; T_4: Foliar application of 0.5 % $ZnSO_4$ at pod initiation; T_5: Foliar application of 0.5 % $FeSO_4$ at pod initiation; T_6: Foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation; T_7: Foliar application of 0.5 % $FeSO_4$ at flower and pod initiation; T_8: Foliar application of 0.5 % $ZnSO_4$ + 0.5% $FeSO_4$at flower and pod initiation; T_9: RDF +Water spray (control). The land was ploughed and made to fine seed bed. The recommended dose of fertilizers (25:50:25NPK kg ha^{-1}) was given for thecrop in the form of urea, diammonium phosphate and muriate of potash as basal dose. Healthy and bold,certified seeds of pigeonpea (BRG-4) were used for sowingwith spacing of 90×15 cm.Weeding and plant protection measures were undertaken as per need and required plant population was maintained by thinning andgap filling. The crops were harvested at their physiological maturity. Growth and yield parameters and yield were recorded at harvest and the economics was worked out based on the cost of inputs, labour costs and price of output during the course of study. Fischer's method of analysis of variance was used for analysis and interpretation of the data as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters of pigeonpea

The data pertaining to growth attributes of pigeonpea at harvest as influenced by agronomic fortification of pigeonpea with Zn and Feare presented in Table 1. Among the different treatments, the treatments (T_8) foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation recorded significantly higher values of growth contributing characters of pigeonpea *viz*., plant height (156.7 cm), total branches per plant (16.8), leaf area (5542.2 cm^2 plant^{-1}) and total dry matter production (118.2 g plant^{-1}) followed by treatment(T_6) foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation (155.8 cm, 16.3 plant^{-1}, 5216.5 cm^2 plant^{-1} and 112.6 g plant^{-1}, respectively).Whereas, significantly lower values noticed in application of RDF only (Absolute control).

The observed outcomes can be attributed to the enhanced availability of zinc and iron in deficient soil, facilitated through foliar application of zinc sulphate and iron sulphate. This process involves their better absorption and translocation within the plant. The foliar spray of zinc (Zn) and iron (Fe) in a bioavailable form is readily taken up by the aerial parts of the plant, subsequently moving towards the growing tip. This action stimulates auxin activity at the crop's growth point, thereby enhancing quality of the young shoot. Zinc plays a crucial role in regulating chlorophyll and carotenoid synthesis, vital for optimal functioning of the photosynthetic system. The application of zinc promotes activity in meristematic cells and cell elongation, positively impacting metabolic processes. The heightened metabolic activity, facilitated by increased nutrient supply, leads to greater accumulation of dry matter in leaves. This accumulation aids in maintaining an active photosynthetic area for an extended period, contributing significantly to overall plant growth in terms of dry matter production.The higher dry matter production due to the application of zinc is ascribed to the vigorous and enhanced plant growth and also to higher leaf area development that aided in the effective interception of light leading to higher dry matter production. This result is in conformity with the findings of Sharma *et al*. (2010) in pigeonpea and Verma *et al.* (2017) in lentil.The lower growth in Absolute control due to poor nutrient uptake compared to lack of synergistic effect in absence of micronutrient.Similar results were also reported by Gowda *et al*. (2014), Hadi *et al.* (2013), Kayan *et al.* (2015) and Hossain *et al*. (2016).

Yield attributes of pigeonpea

The data related to yield attributes *viz*., number of pods per plant, number of seeds per pod, pod yield per plant (g), seed yield per plant (g), stalk yield (g plant^{-1}) and test weight of pigeonpea as influenced by agronomic fortification with Zn and Fe are presented in Table 2. The foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation resulted in significantly higher number of pods (98.5 plant^{-1}), number of seeds (5.4

pod^{-1}), pod yield (128.5 g plant^{-1}), seed yield (83.5 g plant^{-1}), stalk yield (116.2 g plant^{-1}) and test weight (15.7 g) followed by T_6, whereas lower number of pods per plant, number of seeds per pod, pod yield per plant, seed yield per plant, stalk yield per plant and test weight (87.2, 4.3, 84.5, 52.5, 62.5 and 14.0, respectively) were recorded with application of RDF only (T_1). This might be due to lower availability of major and micronutrient in soil, lower nutrient uptake, reduced photosynthates production which causes lower yield attributing characters and resulted in lower yieldand Higher seed yield plant^{-1} may be due to fulfillment of the demand of crop by higher assimilation and translocation of photosynthates from source to sink and better role of zinc during reproductive phase of crop growth. Seed yield plant^{-1} was governed by number of pods plant-1, number of seeds pod^{-1} and 100 seed weight. Similar results were also reported by Gowthami and Ananda (2015), Srikanth Babu *et al.* (2012)and Debroy *et al.* (2013)

Yield of pigeonpea

The data relating to yield of pigeonpea that differed significantly due to influence of agronomic fortification with Zn and Fe are depicted in Table 3. Significantly higher seed yield (1056 kg ha^{-1}) and stalk yield (2503 kg ha^{-1}) were recorded with the foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation followed by foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation (1035 and 2432 kg ha^{-1}, respectively).Whereas, significantly lower yield was noticed in application of RDF only (972 and 2090 kg ha^{-1}, respectively).The harvest index of pigeonpea was not influenced by agronomic fortificationwith Zn and Fe.

The increasing in the yield and yield attributes might be due to foliar application of micronutrients which were directly absorbed by plants thereby increasing the metabolism of the plants resulting in increased synthesis of photosynthetic products. These micronutrients also helped in efficiently transferring photosynthetic products from source to sink, thereby increasing seed weight in pods ultimately resulting in higher seed yield. Higher seed weight might be due to higher dry matter accumulation, better nutrient uptake (N, P, K, Zn and Fe) and translocation to reproductive parts and involvement of zinc in various enzymatic processes which helps in catalyzing reaction for growth finally leading to development of more yield attributing characters like number of pods per plant, pod weight, 100 seed weight, and seed yield. Similar findings were reported by Shivanand *et al*. (2017), Ramaprasad *et al*. (2017) and Yashona*et al*. (2020).

Economics of pigeonpea

Effect of agronomic fortification with Zn and Fe on economics of pigeonpea is described in Table 4. Maximum gross returns (Rs. 69696 ha^{-1}), net returns (Rs. 32859ha^{-1}) and B:C ratio (1.89) were recorded with foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation(T_8).The marginal increase in cost of production compared to rest of the treatment with higher magnitude of yield enhancement resulted in higher yields, gross returns, net return and benefit cost ratio. Almost similar result found in Mukundagowda*et al.,* (2014), Rathod *et al.,* (2016) and Jha *et al.,* (2015)

Conclusion

Based on the results it can be concluded that foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation recorded higher growth attributes, yield attributes, seed yield, stalk yield, gross returns, net returns and B:C ratio. It was found to be optimum and profitable and produced higher grain yield in pigeonpea with foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation Shivanand *et al*. (2017).

Table 01: Effect of agronomic fortification of pigeonpea with Zn and Fe on growth parameter ofpigeonpea at harvest

Treatments	Plant height (cm)	Total number of branches plant^{-1}	Total leaf area (cm^2 plant^{-1})	Total dry matter accumulation (g plant^{-1})

T_1: RDF (Absolute control)	149.1	12.4	2786.6	78.7
T_2: Foliar application of 0.5 % $ZnSO_4$ at flower initiation	153.3	15.7	4615.2	104.5
T_3:Foliar application of 0.5 % $FeSO_4$ at flower initiation	151.8	14.7	3994.5	88.5
T_4: Foliar application of 0.5 % $ZnSO_4$ at pod initiation	152.8	15.1	4012.4	97.4
T_5: Foliar application of 0.5 % $FeSO_4$ at pod initiation	151.1	14.2	3546.2	85.2
T_6: Foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation	155.8	16.3	5216.5	112.6
T_7: Foliar application of 0.5 % $FeSO_4$ at flower and pod initiation	154.2	16.0	4968.4	110.5
T_8: Foliar application of 0.5 % $ZnSO_4$ + 0.5% $FeSO_4$ at flower and pod initiation	156.7	16.8	5542.2	118.2
T_9: RDF +Water spray (control)	150.5	13.5	2946.6	74.5
S.Em. ±	5.46	1.13	97.58	2.26
C.D. at 5%	16.37	3.38	280.77	6.49

Table 02: Effect of agronomic fortification of pigeonpea with Zn and Fe on yield attributes of pigeonpea

Treatments	**No of pods plant^{-1}**	**No of seeds pod^{-1}**	**Pod yield (g plant^{-1})**	**Seed yield (g plant^{-1})**	**Stalk yield (g plant^{-1})**	**Test weight (g)**
T_1: RDF (Absolute control)	87.2	4.3	84.5	52.5	62.6	14.0
T_2: Foliar application of 0.5 %	96.1	5.1	115.0	73.0	102.0	14.9

$ZnSO_4$ at flower initiation						
T_3: Foliar application of 0.5 % $FeSO_4$ at flower initiation	92.7	4.8	103.1	65.0	93.0	14.6
T_4: Foliar application of 0.5 % $ZnSO_4$ at pod initiation	94.8	5.0	110.6	69.7	97.2	14.7
T_5: Foliar application of 0.5 % $FeSO_4$ at pod initiation	91.2	4.7	99.1	62.2	87.5	14.5
T_6:Foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation	97.7	5.3	124.3	80.8	112.1	15.6
T_7: Foliar application of 0.5 % $FeSO_4$ at flower and pod initiation	97.2	5.2	122.4	78.3	108.4	15.5
T_8:Foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation	98.5	5.4	128.5	83.5	116.2	15.7
T_9:RDF +Water spray (control)	89.2	4.5	91.2	57.0	76.8	14.2
S.Em. ±	2.89	0.19	5.05	3.31	2.23	0.39
C.D. at 5%	8.67	0.58	15.13	9.93	6.42	1.17

Table 03: Effect of agronomic fortification of pigeonpea with Zn and Fe on yield of pigeonpea

Treatments	Seed yield (kg ha^{-1})	Stalkyield (kg ha^{-1})	Harvest Index
T_1: RDF (Absolute control)	972	2090	0.32
T_2: Foliar application of 0.5 % $ZnSO_4$ at flower initiation	1007	2336	0.30
T_3: Foliar application of 0.5 % $FeSO_4$ at flower initiation	991	2220	0.31

T_4: Foliar application of 0.5 % $ZnSO_4$ at pod initiation	998	2285	0.30
T_5: Foliar application of 0.5 % $FeSO_4$ at pod initiation	987	2181	0.31
T_6:Foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation	1035	2432	0.30
T_7: Foliar application of 0.5 % $FeSO_4$ at flower and pod initiation	1018	2377	0.30
T_8:Foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation	1056	2503	0.30
T_9:RDF +Water spray (control)	981	2158	0.31
S.Em. ±	18.06	61.11	0.06
C.D. at 5%	54.14	183.20	NS

Table 04: Effect of agronomic fortification of pigeonpea with Zn and Fe on economics of pigeonpea

Treatments	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C Ratio

T_1: RDF (Absolute control)	36127	64152	28025	1.78
T_2: Foliar application of 0.5 % $ZnSO_4$ at flower initiation	36481	66462	29981	1.82
T_3: Foliar application of 0.5 % $FeSO_4$ at flower initiation	36443	65406	28963	1.79
T_4: Foliar application of 0.5 % $ZnSO_4$ at pod initiation	36481	65868	29387	1.81
T_5:Foliar application of 0.5 % $FeSO_4$ at pod initiation	36443	65142	28699	1.79
T_6: RDF + Foliar application of 0.5 % $ZnSO_4$ at flower and pod initiation	36781	68310	31529	1.86
T_7: RDF + Foliar application of 0.5 % $FeSO_4$ at flower and pod initiation	36743	67188	30445	1.83
T_8: RDF +Foliar application of 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ at flower and pod initiation	36837	69696	32859	1.89
T_9: RDF +Water spray (control)	36967	64746	27779	1.75

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