RESEARCH ARTICLE Legume Research- An International Journal, Volume 48 Special Issue: 182-187 (November 2025)

Effect of Zinc and Iron Fertilization on Productivity of Pigeon Pea (*Cajanus cajan*) under Rainfed Agro-ecologies of Jammu

Faraaz Farooq[1], Permendra Singh[2], Arvind P. Singh[1], Brinder Singh[2], Rakesh Kumar[1], C. Lalrammawii[1], Joy Samuel MeCarty[1], Hritik Srivastava[1], Swati Mehta[3]

10.18805/LR-5401

ABSTRACT

Background: In the agricultural context of India, pigeon pea assumes a pivotal role as second most important pulse crop. However, owing to their cultivation in zinc and iron deficient soils and limited and unbalanced use of fertilizers its productivity is low. Further, the prevalent rice-wheat based cropping system, aggravates their deficiency and becomes another important factor in the decline in productivity of pulse crops like pigeon pea. Therefore, zinc and iron application through fertilizers can play a crucial role in improving the growth and yield of pigeon pea especially, under rainfed conditions.

Methods: In this study, a field experiment was carried out over two *kharif* seasons in 2021 and 2022. The experiment was conducted under a randomized block design with eleven treatments of zinc and iron, replicated thrice at the Advanced Center for Rainfed Agriculture, Rakh Dhiansar, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu.

Result: The study found that treatment T6-RDF + soil application of $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 5 kg/ha significantly improved growth attributes like plant height, leaf area index, number of branches anddry matter accumulation. It also led to significantly higher yield and yield attributes like pods per plant, seeds per pod, seed weight, seed yield, stalk yield and biological yield.

Key words: Growth, Iron, Pigeon pea, Yield, Zinc.

INTRODUCTION

Pigeon pea (*Cajanus cajan*) is one of the most widely cultivated pulse crops originating from the Indian subcontinent. It is widely cultivated in the tropics and subtropics and is known for its drought tolerating ability. Known for its nutritional richness, pigeon pea provides high protein, fiber, vitamins and potassium, while being low in fat and sodium, making it particularly valuable for India's vegetarian population (Amarteifio *et al*., 2002). Globally, pigeon pea is the fifth most important pulse crop, with India being the second-largest producer. About 40% of Soils in India are deficient in zinc and12.6% are iron deficient, which has an adverse effect on pigeon pea productivity (Shukla *et al*., 2016). Zinc exhibits values in pharmacological activities like enzyme activity, protein synthesis and growth regulation that play important roles in plant metabolism, while iron plays a very important role in chlorophyll and enzyme function besides, in nitrogen fixation. Micronutrient deficiencies find higher expression in cereal-based cropping systems and regions like Jammu and Kashmir, where rice and wheat, which again are poor sources, are major staple foods (Shukla and Mishra, 2020). Keeping in view the nutritional importance of pigeon pea against malnutrition, therefore rectification of soil micronutrient deficiencies assumes immense importance. Earlier workers have reported that foliar and soil application of zinc and iron either alone or in combination led to increased pigeon pea yield under rain-fed conditions of cultivation (Sharma *et al*., 2010; Shukla *et al*., 2014; Saakshi *et al*., 2020). But there is still a lack of information regarding the magnitude of this effect under the specific agro-ecological conditions of Jammu. The present study has investigated the effects of zinc and iron fertilization on pigeon pea growth and its yield under rainfed conditions of Jammu. This study aims at establishing some optimal management practices that could improve productivity for food and nutritional security in this region through investigations of the interaction of these two micro-nutrients with crop performance.

Applying zinc and iron, especially to soils that aren't getting enough of them, becomes an important way to increase pigeon pea yields and help fight malnutrition

[1]Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.
[2]Advance Centre for Rainfed Agriculture, Samba, Jammu-181 133, Jammu and Kashmir, India.
[3]Lovely Professional University, Phagwara-144 411, Punjab, India.

Corresponding Author: Faraaz Farooq, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.
Email: faraazfarooq9086@gmail.com
ORCIDs: 0009-0000-3309-2464; 0000-0002-3269-2019; 0000-0003-3186-3098; 0009-0002-1036-2075; 0009-0001-5097-2313; 0000-0002-9303-874X; 0000-0003-3837-0077; 0009-0002-6048-0125; 0000-0002-3843-8310

How to cite this article: Farooq, F., Singh, P., Singh, A.P., Singh, B., Kumar, R., Lalrammawii, C., MeCarty, J.S., Srivastava, H. and Mehta, S. (2025). Effect of Zinc and Iron Fertilization on Productivity of Pigeon Pea (*Cajanus cajan*) under Rainfed Agro-ecologies of Jammu. *Legume Research.* **48 (Special Issue):** 182-187. doi: 10.18805/LR-5401.

Submitted: 14-08-2024 **Accepted:** 16-12-2024 **Online:** 11-01-2025

(Shukla *et al*., 2014). Recognizing pigeon pea's importance as a nutritious food source, an experiment was conducted to examine the effects of zinc and iron fertilization on the growth and yield of pigeon pea (*Cajanus cajan*) under rainfed conditions of Jammu.

MATERIALS AND METHODS

A field experiment at Advanced Center for Rainfed Agriculture was conducted for consecutive *kharif* seasons of 2021 and 2022 under Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India. Initially, the soil of the field at which experiment was laid out was sandy loam in nature with near to neutral in reaction (6.84). Further, the soil was low in organic carbon (%), available nitrogen (175.2 kg per ha) and DTPA extractable zinc (0.52 m per Kg). However, available phosphorus (12.7 kg per ha) and potassium (115.16 kg per ha) were in medium range with sufficient quantity of available iron (0.52 mg per kg). The experiment was laid under randomized block design with three replications and eleven treatments *viz.* T_1-RDF-25 kg N_2: 50 kg P_2O_5: 30 kg K_2O (Absolute control), T_2-RDF + soil application of $ZnSO_4$ @ 25 kg/ha, T_3-RDF + soil application of $ZnSO_4$ @ 18.75 kg/ha(75% of 25 kg ha^{-1}), T_4-RDF + soil application of $FeSO_4$ @ 5 kg/ha, T_5-RDF + soil application of $FeSO_4$ @ 3.75 kg/ha (75% of 5 kg/ha), T_6-RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 5 kg ha^{-1}, T_7-RDF + Soil application of 18.75 kg/ha 0f ZnSO + 3.5 kg/ha of $FeSO_4$ T_8-RDF + foliar application of $ZnSO_4$ @ 0.50% at flowering and pod initiation, T_9-RDF + foliar application of $FeSO_4$ @ 0.50% at flowering and pod initiation, T_{10}-RDF + foliar application of $ZnSO_4$ @ 0.50% + $FeSO_4$ @ 0.50% at flowering and pod initiation and T_{11}-RDF + water spray at flowering and pod initiation (Control). The nutrients *viz*. N, P_2O_5 and K-$_2$O were applied as per the recommendations through urea, DAP (di-ammonium phosphate) and MOP (muriate of potash) at the time of sowing. Zinc and iron were applied to the soil through zinc sulfate hepta-hydrate while foliar sprays were applied during the flowering and pod initiation stages of pigeon pea. The sowing of crop was done in 15th July and harvested on 23rd of December. In order to reduce the competition between weeds and crop two hand weedings were given at 25 days after sowing (DAS) and at 45 DAS. The data for the growth and yield attributes except for the dry matter accumulation was recorded by randomly selection of five plants from each plot, while the seed and stalk yield were measured on net plot basis and presented in kilograms per hectare. Plant samples from a running meter row were taken from the randomly selected rows at distinct growth stages by cutting the plants closer to the surface of soil. Branches and stem were separated, sun dried and moved to oven for drying at a temperature of 65±5°C till a constant weight was obtained. The total dry matter accumulation using a weighing scale was recorded by summing dry weight of branches and stem and expressed as gram running $meter^{-1}$ their weights were taken. The pigeon pea crop was sown at spacing of 60×15 cm in a plot size of 16.6 m^2 (4.2 m × 3 m). The data collected was subjected to statistical analysis using the suitable method of analysis of variance, as outlined by Fisher in 1950. A critical difference was determined to compare treatments at a significance level of 5%. During the course of experiment the first year (2021) marked a total rainfall of 312 mm, with 53.6 mm during the 29th SMW providing adequate soil moisture for sowing and 73.2 mm during the 30th SMW maintaining optimum moisture for germination. Moisture was sufficiently maintained in the soil until the 38th SMW due to continued rainfall. However, a dry spell occurred from the 45th to the 51st SMW, coinciding with the flowering and pod setting stages, which are critical and vulnerable to moisture stress. Despite this, the drought-tolerant pigeon pea survived well. Temperature requirements were met, with 30-35°C during germination, 20-25°C during flowering andwarm temperatures during maturity. The maximum weekly temperature ranged from 16.9-36.1°C, while the minimum ranged from 5.2-24.7°C, with the highest recorded temperature (36.1°C) during the 31st SMW and the lowest (5.2°C) during the 51st SMW. In 2022, total rainfall increased slightly to 325 mm, with 55.0 mm during the 29th SMW and 75.0 mm during the 30th SMW, providing slightly better conditions for sowing and germination. The dry spell from the 45th to 51st SMW persisted, but the plant again tolerated the conditions. Temperature ranges were similarly optimal, with a slight increase in both maximum (17.0-36.2°C) and minimum (5.3-24.8°C) temperatures. The maximum temperature (36.2°C) occurred in the 31st SMW andthe minimum (5.3°C) in the 51st SMW. The increase in rainfall and minor temperature fluctuations did not lead to major changes in plant performance, though cooler nights during maturity may still have slightly affected yield.

RESULTS AND DISCUSSION

Effect of zinc and iron on growth of pigeon pea

The plant height of the pigeon pea showed a progressive increase across both the years of the study, 2021 and 2022, with the application of zinc and iron through soil or foliar methods. The data presented in Table 1 show a significant increase in plant height when compared to the control. Under the T_6 treatment (RDF + soil application of $ZnSO_4$ @ 25 kg /ha¹ + $FeSO_4$ @ 5 kg/ha), the maximum plant heights of 182.33 cm and 183.96 cm were recorded in 2021 and 2022, respectively. This was statistically at par with T_7, RDF + soil application of $ZnSO_4$ @ 18.75 kg/ha + $FeSO_4$ @ 3.5 kg ha^{-1}; T_{10}, RDF + foliar application of $ZnSO_4$ @ 0.50% + $FeSO_4$ @ 0.50% at flowering and pod initiation; T_8, RDF + foliar application of $ZnSO_4$ @ 0.50% at flowering and pod initiation; T_2, RDF + soil application of $ZnSO_4$ @ 25 kg/ha; and T_3, RDF + soil application of $ZnSO_4$ @ 18.75 kg /ha. Notable height of plants is seemingly an effect of combined application of Zn and Fe, as this combination likely showed synergy on pigeon pea growth. Zinc and iron play a vital role in most of the physiological processes connected with

enzyme activation, synthesis of chlorophyll andcell division. The synergistic interaction between the two micronutrients likely raised meristematic cell activity, resulting in improved shoot growth due to enhanced cell division and elongation. This was the probable reason for the substantially increased height of the treated pigeon pea plants. The results were in conformity with the findings of Behera *et al*. (2020) and Saakshi *et al*. (2020).

Over 2021 and 2022, the application of zinc and iron through the soil or foliar route showed a considerable effect on some key growth parameters in pigeon pea with regard to LAI, the number of branches per plant anddry matter accumulation. From Table 1, treatment T_6 (RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 5 kg ha^{-1}) invariably recorded the highest values for LAI, the number of branches per plant anddry matter accumulation in both 2021 and 2022, with values of 1.74 and 1.76, 42.88 and 42.99 and 460.25 and 463.18 g running m^{-1}, respectively. The results were statistically at par with T_7, RDF + soil application of $ZnSO_4$ @ 18.75 kg ha^{-1} + $FeSO_4$ @ 3.5 kg ha^{-1}; T_{10}, RDF + foliar application of $ZnSO_4$ @ 0.50% + $FeSO_4$ @ 0.50% at flowering and pod initiation; T_8, RDF + foliar application of $ZnSO_4$ @ 0.50% at flowering and pod initiation; T_2, RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1}; and T_3, RDF + soil application of $ZnSO_4$ @ 18.75 kg ha^{-1}.

The high improvement in these growth parameters can be attributed to the combined and balanced application of zinc and iron with RDF. Quite likely, the adequate supply of these micronutrients checked premature leaf fall and facilitated cell division and cell enlargement, which, in turn, promoted leaf expansion both in length and breadth, resulting in a high leaf area index. With improved leaf area, the efficiency of photosynthesis is improved andhence assimilation and translocation of photosynthates become better. This further supports an increase in the growth of more branches and higher dry matter accumulation in pigeon pea. The revealed results are in line with findings of Pal *et al*. (2021) and Khara *et al*. (2022).

Effect of zinc and iron on yield attributes of pigeon pea

The effect of zinc and iron on yield attributes of pigeon pea was assessed andthe results showed significant improvement in key yield parameters-number of pods per plant, number of seeds per pod and 100-seed weight-after the application of zinc and iron. Table 2 presents data showing a notable increase in these yield attributes.

In the *kharif* seasons of 2021 and 2022, the highest pods per plant, seeds per pod and100-seed weight were recorded with a maximum value of 105.20 and 105.24, 4.02 and 4.09 and10.61 g and 10.63 g, respectively, under the treatment T_6 (RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 5 kg ha^{-1}). This was statistically at par with T_7, RDF + soil application of 18.75 kg ha^{-1} of $ZnSO_4$ + 3.5 kg ha^{-1} of $FeSO_4$; T_{10}, RDF + foliar application of $ZnSO_4$ @ 0.50% + $FeSO_4$ @ 0.50% at flowering and pod initiation; T8, RDF + foliar application of $ZnSO_4$ @ 0.50% at flowering and pod initiation; T_2, RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1} and T_3, RDF + soil application of $ZnSO_4$ @ 18.75 kg ha^{-1}. Improvement in yield parameters may be attributed to the fact that, during the growing period, the balanced availability of macro- and micronutrients, especially zinc and iron, was maintained. Zinc works as a coenzyme in photosynthesis and also helps in producing the substrates essential for plant growth and development. Iron application, besides improving photosynthetic processes,

Table 1: Growth of pigeon pea as influenced by the zinc and iron fertilization.

Treatments	Plant height (cm)		Leaf area index		No. of Branches		Dry matter accumulation (g per running meter)	
	2021	2022	2021	2022	2021	2022	2021	2022
T_1	141.91	142.71	0.82	0.84	27.86	27.78	302.10	302.54
T_2	174.23	174.76	1.51	1.52	38.67	38.97	430.25	432.28
T_3	167.96	169.11	1.49	1.51	36.82	36.88	412.68	415.89
T_4	154.35	156.08	1.10	1.10	31.22	31.28	325.61	326.98
T_5	152.48	153.69	1.02	1.04	30.95	30.99	323.56	324.18
T_6	182.33	183.96	1.74	1.76	42.88	42.99	460.25	463.18
T_7	178.30	182.02	1.68	1.71	41.33	41.85	452.49	454.87
T_8	171.54	172.45	1.63	1.65	36.84	37.05	425.67	427.14
T_9	160.41	163.13	1.37	1.38	34.67	34.71	370.25	372.09
T_{10}	176.47	180.45	1.85	1.87	39.56	39.67	450.13	454.01
T_{11}	150.08	152.63	1.01	1.08	30.62	30.65	332.24	325.07
SEm (±)	6.05	6.09	0.099	0.10	2.07	2.13	16.54	16.74
CD (5%)	17.86	17.91	0.292	0.303	6.09	6.29	48.79	49.23

T_1: RDF (Control); T_2: RDF + $ZnSO_4$ (25 kg/ha, soil); T_3: RDF + $ZnSO_4$ (18.75 kg/ha, soil); T_4: RDF + $FeSO_4$ (5 kg/ha, soil); T_5: RDF + $FeSO_4$ (3.75 kg/ha, soil); T_6: RDF + $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (5 kg/ha, soil); T_7: RDF + $ZnSO_4$ (18.75 kg/ha) + $FeSO_4$ (3.5 kg/ha, soil); T_8: RDF + $ZnSO_4$ (0.5%, foliar at flowering and pod initiation); T_9: RDF + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{10}: RDF + $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{11}: RDF + water spray (foliar at flowering and pod initiation).

might have facilitated better partitioning of photosynthates, enhancing source-sink relationships.

These findings are in line with earlier studies in chickpea by Deshlahre and Banjara, (2019); Verma *et al*., 2020, in various pulse crops by Pal *et al*. (2019) and Pal *et al*. (2021); in pigeon pea by Saakshi *et al*. (2020); in chickpea by Kharra *et al*. (2022) and in green gram by Zafar *et al*. (2023).

Effect of zinc and iron on yield of pigeon pea

Application of zinc and iron significantly improved both seed and stalk yield of pigeon pea under study during 2021 and 2022. The yield data of both the years is presented in Table 3 for seed and stalk yield, respectively. The treatment T_6 (RDF + Soil Application of $ZnSO_4$ @ 25 kg ha^{-1}+ $FeSO_4$ @ 5 kg ha^{-1}) recorded the highest grain yield of 1764 kg ha^{-1} and 1771 kg ha^{-1} in 2021 and 2022, respectively. Similarly, the highest stalk yield was observed in T_6, with 6151 kg ha^{-1} in 2021 and 6160 kg ha^{-1} in 2022. Although T_6 outperformed other treatments, it was statistically at par with T_7 (RDF + soil application of 18.75 kg ha^{-1} $ZnSO_4$ + 3.5 kg ha^{-1} $FeSO_4$), T_{10} (RDF + foliar application of $ZnSO_4$ @ 0.50% + $FeSO_4$ @ 0.50% at flowering and pod initiation), T_8 (RDF + foliar application of $ZnSO_4$ @ 0.50% at flowering and pod

Table 2: Yield attributes of pigeon pea as influenced by the zinc and iron.

Treatment	Number of pods plant		Number of seeds pod^{-1}		100 seed weight (g)	
	2021	2022	2021	2022	2021	2022
T_1	78.27	78.28	3.13	3.13	8.11	8.10
T_2	99.03	99.05	3.74	3.77	10.16	10.18
T_3	96.77	96.81	3.56	3.56	9.78	9.81
T_4	83.77	83.78	3.23	3.25	8.29	8.28
T_5	84.47	84.49	3.17	3.18	8.26	8.28
T_6	105.20	105.24	4.02	4.09	10.61	10.63
T_7	103.07	103.11	3.97	3.99	10.56	10.58
T_8	97.50	97.52	3.65	3.68	9.97	9.98
T_9	89.23	89.25	3.38	3.38	9.69	9.68
T_{10}	102.30	102.36	3.77	3.84	10.32	10.33
T_{11}	80.20	80.24	3.19	3.22	8.27	8.28
SEm (±)	3.01	3.03	0.17	0.18	0.35	0.36
CD (5%)	8.89	8.92	0.51	0.52	1.03	1.02

T_1: RDF (Control); T_2: RDF + $ZnSO_4$ (25 kg/ha, soil); T_3: RDF + $ZnSO_4$ (18.75 kg/ha, soil); T_4: RDF + $FeSO_4$ (5 kg/ha, soil); T_5: RDF + $FeSO_4$ (3.75 kg/ha, soil); T_6: RDF + $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (5 kg/ha, soil); T_7: RDF + $ZnSO_4$ (18.75 kg/ha) + $FeSO_4$ (3.5 kg/ha, soil); T_8: RDF + $ZnSO_4$ (0.5%, foliar at flowering and pod initiation); T_9: RDF + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{10}: RDF + $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{11}: RDF + water spray (foliar at flowering and pod initiation).

Table 3: Yield of pigeon pea as influenced by the zinc and iron fertilization.

Treatment	Seed yield (kg /ha)		Stalk yield (kg/ha)	
	2021	2022	2021	2022
T_1	1365	1368	4865	4869
T_2	1672	1681	5782	5788
T_3	1630	1638	5621	5630
T_4	1435	1440	4996	4998
T_5	1418	1423	4915	4921
T_6	1764	1771	6151	6160
T_7	1730	1734	6010	6017
T_8	1657	1659	5699	5709
T_9	1534	1537	5429	5432
T_{10}	1704	1711	5719	5749
T_{11}	1415	1419	4996	5004
SEm (±)	46	48	180	184

T_1: RDF (Control); T_2: RDF + $ZnSO_4$ (25 kg/ha, soil); T_3: RDF + $ZnSO_4$ (18.75 kg/ha, soil); T_4: RDF + $FeSO_4$ (5 kg/ha, soil); T_5: RDF + $FeSO_4$ (3.75 kg/ha, soil); T_6: RDF + $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (5 kg/ha, soil); T_7: RDF + $ZnSO_4$ (18.75 kg/ha) + $FeSO_4$ (3.5 kg/ha, soil); T_8: RDF + $ZnSO_4$ (0.5%, foliar at flowering and pod initiation); T_9: RDF + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{10}: RDF + $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%, foliar at flowering and pod initiation); T_{11}: RDF + water spray (foliar at flowering and pod initiation).

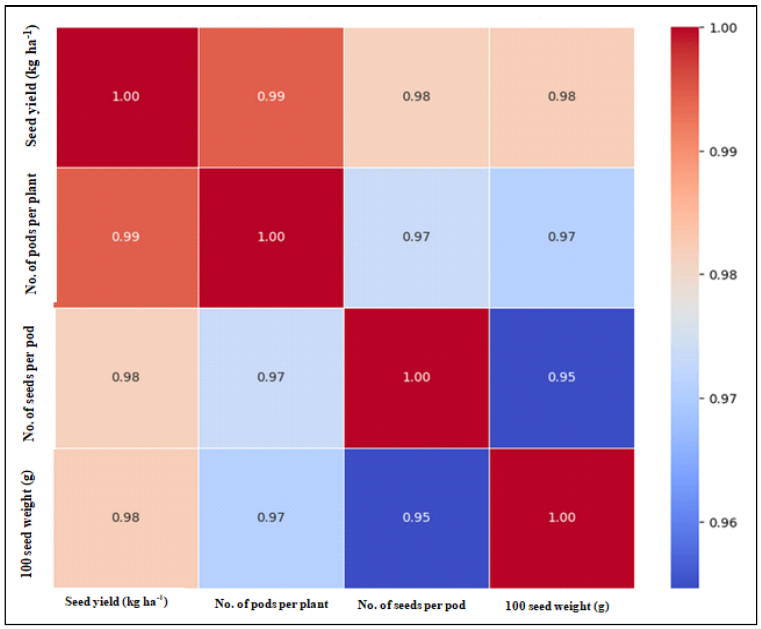


Fig 1: Correlation matrix between yield and yield attributes of pigeon pea.

initiation), T_2 (RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1}) and T_3 (RDF + soil application of $ZnSO_4$ @ 18.75 kg ha^{-1}).

The combined application of Zn and Fe can thus be associated with improvements in seed and stalk yield, likely because of enhancement in nutrient availability and uptake promoted by early root growth for efficient nutrient absorption. This, in turn, supported better plant development, leading to increased number of pods per plant, seeds per pod and 100-seed weight-key contributors to yield enhancement.

Correlation analysis justifies these findings. A heat map presented in Fig 1 shows the relationship of seed yield with yield attributes. The deep red colors indicate a very strong positive correlation, close to 1, of seed yield with the number of pods per plant, seeds per pod and 100-seed weight. All of these were very significantly correlated at 0.99, 0.98 and 0.98, respectively, thus proving that the improvement in these yield attributes directly contributes to improvement in overall yield.

These findings are in agreement with earlier reports, including those in pigeon pea by Saakshi *et al*. (2020) and Verma *et al*. (2020), in chickpea by Pal *et al*. (2023) and Kharra *et al*. (2022) andin moth bean by Devarnavadgi *et al*. (2023). These consistent findings across independent studies further confirm the potential role of zinc and iron fertilization in improving the yield attributes and overall yield of legume crops.

Significant increase in yield of pigeon pea with the zinc and iron fertilization is in conformity with the findings of Saakshi *et al*. (2020) and Verma *et al*. (2020) in pigeon pea, Pal *et al*. (2023) and Kharra *et al*. (2022) in chickpea and Devarnavadgi *et al*. (2023) in mothbean.

CONCLUSION

A two-year study determined that the optimal approach for enhancing pigeon pea growth and productivity involves applying $ZnSO_4$ at a rate of 25 kg/ha and $FeSO_4$ at 5 kg/ha, in combination with the recommended dose of fertilizers (RDF). This method significantly improved the overall development and yield of the crop, suggesting it as the most effective practice for pigeon pea cultivation.

ACKNOWLEDGEMENT

The present study was supported by SKUAST-Jammu.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Amarteifio, J.O., Munthali, D.C., Karikari, S.K. and Morake, T.K. (2002). The composition of pigeon peas [*Cajanu scajan* (L.) Mill sp.] grown in Botswana. *Plant Foods for Human Nutrition.* **57(2):** 173-177.

Behera, S.K., Shukla, A.K., Tiwari, P.K., Tripathi, A., Singh, P., Trivedi, V. and Das, S. (2020). Classification of pigeonpea (*Cajanus cajan* L.) genotypes for zinc efficiency. *Plants.* **9(8):** 952.

Deshlahare, H. and Banjara, G.P. (2019). Impact of biofortification of zinc and iron on growth parameters and yields of chickpea (*Cicer arietinum* L.) through agronomic intervention in Chhattisgarh plains. *Journal of Pharmacognosy and Phytochemistry*. **8(6):** 383-386.

Devarnavadgi, M.S., Yadahalli, V.G., Kuligod, V.B. and Yadahalli, G.S. (2023). Influence of zinc and iron application on yield, quality and economics of mothbean in rainfed conditions of Karnataka. *International Journal of Statistics and Applied Mathematics.* **8(5):** 614-618

FAO, (2023). Food and Agriculture Organization Statistics. Available at URL http://www.fao.org. Accessed on 27 March, 2023.

Galera, S., Rojas, E., Sudhakar, D., Zhu, C., Pelacho, A.M., Capell, T. and Christou, P. (2010). Critical evaluation of strategies for mineral fortification of staple food crops. *Transgenic Research*. **19(2):** 165-180.

Kharra, R., Shukla, U.N., Dhayal, B.C. Choudhary, R., Raiger, P.R. and Bijarnia, K.K. (2022). Agronomic biofortification of zinc and iron on yield potential and zinc fortification in chickpea (*Cicer arietinum* L.) varieties under Arid Western Plains Zone of Rajasthan. *Legume Research*. **23(1):** 1-6. doi: 10.18805/LR-4804.

MukundGowda, K.M., Halepyati, A.S. and Koppalkar, B.G. (2015). Yield, nutrient uptake and economics of pigeonpea [*Cajanus cajan* (L.) Mill sp.] as influenced by soil application of micronutrients and foliar spray of macronutrients. *Karnataka Journal of Agricultural Sciences*. **28(2):** 266-268.

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

Pal, V., Singh, G. and Dhaliwal, S.S. (2021). A new approach in agronomic biofortification for improving zinc and iron content in chickpea (*Cicer arietinum* L.) grain with simultaneous foliar application of zinc sulphate, ferrous sulphate and urea. *Journal of Soil Science and Plant Nutrition.* **21(2):** 883-896.

Pal, V., Singh, G. and Dhaliwal, S.S. (2023). Effects of sequential and tank mix applications of zinc, iron and nitrogen on symbiotic parameters, productivity and economics of chickpea (*Cicer arietinum* L.) under field conditions. *Journal of Soil Science and Plant Nutrition.* **23(2):** 2673-2686.

Saakshi, R.A., Rathod, P.S., Rachappa, V., Dodamani, B.M. and Ananda, N. (2020). Growth, yield and economics of pigeonpea as influenced by biofortification of zinc and iron. *International Journal of Current Microbiology and Applied Sciences.* **9(2):** 3088-3097.

Sharma, A., Nakul, H.T., Jelgeri, B.R. and Surwenshi, A. (2010). Effect of micronutrients on growth, yield and yield components in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Research Journal of Agricultural Sciences.* **1(2):** 142-144.

Shukla, A.K., Tiwari, P.K. and Prakash, C. (2014). Micronutrients deficiencies vis-a-vis food and nutritional security of India. *Indian Journal of Fertilizers.* **10(12):** 94-112.

Shukla, A.K., Tiwari, P.K., Pakhare, A. and Prakash, C. (2016). Zinc and iron in soil, plant, animal and human health. *Indian Journal of Fertilizers*. **12:** 133-149.

Shukla, U.N. and Mishra, M.L. (2020). Present scenario, bottlenecks and expansion of pulse production in India: A review. *Legume Research*. **43(4):** 461-469. doi: 10.18805/LR-3998.

Taliee, A. and Sayadian, K. (2000). Effect of supplemental irrigation and plant nutrient in chickpea (dry farming). *Journal of Agronomy and Crop Science*. **2:** 213-218.

Verma. H, Shahi. P.U., Chaurasia, P. and Kumawat, L. (2020). Effect of mode of micronutrients application on growth and yield of pigeon pea (*Cajanus cajan* L.) in sandy loam soil. *International Journal of Current Microbiology and Applied Sciences.* **9(3):** 17-24.

Zafar, M., Ahmed, S., Munir, M.K., Zafar, N., Saqib, M., Sarwar, M.A. and Gulnaz, A. (2023). Application of zinc, iron and boron enhances productivity and grain biofortification of mungbean. *Phyton.* **92(4):** 983-999.