LR-5152
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RESEARCH ARTICLE **Legume Research- An International Journal**

Effect of Zinc Nutrition on Lathyrus (*Lathyrus sativus* L.) under Varying Sowing Dates in the Gangetic Plains

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10.18805/LR-5152

ABSTRACT

Background: In the lower Gangetic plains, which have typical short winters and Zn-deficient soil, identifying a temporally flexible sowing window with adequate Zn fertilization assumes importance to produce Zn-dense lathyrus in rice-based systems. The current study was conducted to evaluate the effects of sowing dates and Zn nutrition on growth, Zn enrichment and economics of lathyrus.
Methods: The experiment was laid out in a split plot design with three replicates comprising two sowing dates (14th and 29th November) in main plots and eight Zn nutrition encompassing various Zn application methods and method-specific doses in the sub-plots.
Result: Late sowing with foliar spraying of 1.0% ZnSO$_4$ at pre-flowering and pod development stages significantly improved growth traits and yield, while fetching maximum economic benefits in lathyrus. Although sowing dates exerted no significant effect, foliar spraying with 1.0% ZnSO$_4$ significantly improved Zn concentration in lathyrus seed (30.36 ppm). Hence, under inevitable late sowing conditions, lathyrus is an ideal choice when accommodated with adequate Zn fertilization since it is capable of sustaining adequate productivity and nutritive values under suboptimal conditions because of its ability to strike a balance between root and shoot growths.

Key words: Economics, Foliar spray, Lathyrus, Seed zinc concentration, Sowing dates, Yield, Zinc fertilization.

INTRODUCTION

Prolonged use of input-intensive technologies in rice-wheat/ rice-rice cropping patterns has exhausted the natural resource base of the Indo-Gangetic plains, resulting in declining total factor productivity of the system. Thus, the incorporation of pulses in cereal-based cropping sequences under such a scenario not only improves soil health and system productivity but also ensures food and nutritional security by establishing a sustainable agri-food system (Maji *et al.,* 2019). The relatively higher stress tolerance of lathyrus (*Lathyrus sativus* L.) and its ability to withstand unfavourable weather conditions, along with minimal external input demand, make it an ideal pulse crop for resource-poor farmers. Lathyrus is rich in protein and different minerals, making it a preferred choice among the economically weaker sections of society due to its nutritive value and cheaper market price than other pulses. Additionally, due to its nutrient-dense stover, it is steadily gaining popularity as a forage crop and is a possible alternative to the nutritionally deficient paddy straw for animal feed. Despite the multiple agro-ecological and nutritional benefits of lathyrus, limited research interventions to improve lathyrus production have been taken up globally till date. The primary reason behind this paucity of research is the presence of the neurotoxin β-N-oxalyl-l-α,β-di amino-propionic acid (β-ODAP) in lathyrus stover and grains. Prolonged consumption of lathyrus causes lathyrism, a neurological condition that results in lower limb paralysis.

The timely sowing of winter crops in the lower Gangetic plains is often hindered by the shifting monsoon cycle, frequent occurrence of adverse weather events, late transplanting and the long duration of preceding monsoon rice. Therefore, to successfully include lathyrus into the region's commonly practised rice-based systems, it is crucial to identify a temporally flexible sowing window that complies with the prevailing weather. Moreover, the zinc-deficient lowland rice soil severely limits the productivity of winter pulses grown after monsoon rice. The wide-ranging role of zinc in enzymatic activity, reproductive biology and stress tolerance makes it an important determinant of the final yield (Liu *et al.,* 2019). Zinc fertilization is also an effective agronomic biofortification strategy to yield Zn-dense crops (Chaudhary *et al.,* 2022). Hence, the current study was taken up to assess the effect of sowing dates and zinc nutrition on lathyrus growth, productivity, nutrient enrichment and economics.

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How to cite this article: Majee, A., Maji, S., Bhowmick, U.R., Mondal, S., Biswas, P., Mondal, A., Saharoy, A. and Paul, A. (2023). Effect of Zinc Nutrition on Lathyrus (*Lathyrus sativus* L.) under Varying Sowing Dates in the Gangetic Plains. Legume Research. DOI; 10.18805/LR-5152

Submitted: 10-04-2023 **Accepted:** 09-11-2023 **Online**: 07-12-2023

MATERIALS AND METHODS

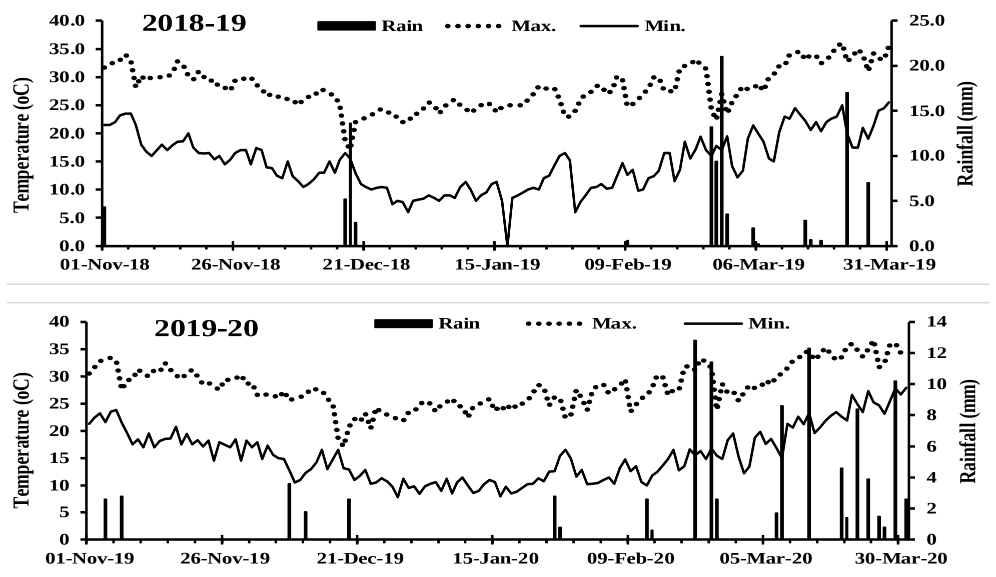
A field study was set up during the winter seasons of 2018-19 and 2019-20 at 'AB' block farm, Bidhan Chandra Krishi Viswavidyalaya, to evaluate the effects of date of sowing and Zn fertilization on lathyrus. The study site's geographical location was 22°58′45″N and 88°25′15″E, with an altitude of 9.75 m above mean sea level. The texture of the experimental soil was sandy clay loam with a neutral pH (7.3). The nutrient status of the soil was 0.50%, 285.11 kg ha^{-1}, 28.43 kg ha^{-1}, 153.60 kg ha^{-1} and 0.54 ppm organic carbon, available nitrogen, phosphorus, potassium and DTPA extractable Zn, respectively. Year-wise temperature and rainfall data during the crop-growing period are provided in Fig 1.

The experimental design of the field study was a split plot with three replications. The main plot comprised two dates of sowing, *viz.,* D_1: Early sowing (14 November) and D_2: Late sowing (29 November), while various Zn nutrition protocols were allotted to sub-plots, *viz.,* Zn_1: Control (No zinc application), Zn_2: 15 kg $ZnSO_4$ ha^{-1} as basal, Zn_3: 20 kg $ZnSO_4$ ha^{-1} as basal, Zn_4: 25 kg $ZnSO_4$ ha^{-1} as basal, Zn_5: 0.5% $ZnSO_4$ foliar spray, Zn_6: 1.0% $ZnSO_4$ foliar spray, Zn_7: Seed priming with 0.05% zinc solution, Zn_8: Seed priming with 0.1% zinc solution. The foliar spraying for treatments Zn_5 and Zn_6 was done at the pre-flowering and pod initiation stages and the priming duration for Zn_7 and Zn_8 was 6 hours.

The crop variety Prateek was sown with a spacing of 30 cm × 10 cm in a sub-plot size of 5 m × 4 m. A blanket basal dose of 20 kg N, 40 kg P_2O_5 and 20 kg K_2O per ha in the forms of urea, single superphosphate and muriate of potash, respectively, was applied. Observations on plant height, root and shoot biomass and leaf area index were recorded for each treatment combination at 30, 50, 70 and 90 days after sowing (DAS). At harvest, the number of pods plant^{-1}, 100 seed weight (g), seed yield (kg ha^{-1}) and harvest index were recorded. For treatment-wise economic analysis, the prevalent market costs of the inputs, labour charges and the farm gate price of the output in West Bengal were considered.

For zinc estimation, 0.5 g of ground seed and stover samples from each plot were placed separately in crucibles, followed by dry ashing in a muffled furnace at 550°C for 4 h. On the following day, 10 ml of 6.0 N HCl was added to the cool dry ash of each sample and thoroughly mixed. An aliquot of each sample was then collected after filtering through Whatman No. 1 filter paper. The volume makeup of the aliquots to 50 ml with double distilled water was done and finally the Zn concentration was estimated using an atomic absorption spectrophotometer (Perkin Elmer PinAAcle-900F, United States) and expressed in ppm.

The treatment means were compared using Tukey's HSD (honest significant difference) at $p \leq 0.05$ after the relevant data were statistically examined by the analysis of variance (ANOVA) technique for split-plot design. The mean data of two years are presented here because ANOVA showed no significant variation ($p > 0.05$) between the years, among treatments or year x treatment interactions. The interaction effect between sowing dates and Zn nutrition was also found to be non-significant ($p > 0.05$, data not shown).



¥ Max.- Maximum temperature, Min.- Minimum temperature

Fig 1: Year-wise distribution of temperature (°C) and rainfall (mm) during the experimental period.

RESULTS AND DISCUSSION

Plant height

The late-sown crop had significantly taller plants than the early-sown crop throughout the crop-growing period (Table 1). The early sown crop was exposed to a substantially higher average maximum temperature (28.7°C-28.8°C) during the first 30 DAS in both years of experimentation, which might have restricted the plant height initially. A mean daily maximum temperature of 25°C is considered the ceiling for heat stress in cool-season crops (Wahid *et al.* 2007). The late sown crop in the present experiment experienced favourable average maximum temperatures of 25.3°C and 25.2°C during the initial period in 2018-19 and 2019-20, respectively, which possibly improved its vegetative growth as evident from the increased crop height.

Zn nutrition significantly improved crop height compared to control because of its contribution to chlorophyll, cell division, meristematic physiology, cell volume, the formation of the cell wall and photosynthesis (Liu *et al.,* 2019). Among the Zn fertilizations, basal application of $ZnSO_4$ at a rate of 25kg ha^{-1} recorded significantly higher crop height (36.67 cm-110.63 cm) throughout the crop growth period.

Leaf area index

A sharp increase in LAI was observed after 50 DAS. In the present experiment, LAI continued to increase even after 50% flowering, with the maximum LAI being recorded at 90 DAS (Table 1). In determinate crops, the highest LAI is attained before the reproductive stage, but in indeterminate crops like pulses, the maximum LAI may be obtained after flowering. Congenial weather conditions might have facilitated better LAI development in D_2 sowing in the early stages and this early head start helped it to consistently maintain a higher LAI throughout the growing period. However, with the dip in mean temperature (17.3-18.2°C), the D_1 sown crop showed a sharp increase in LAI development during 50-90 DAS, indicating canopy adjustment in response to favourable weather conditions (Tesfaye *et al.,* 2006).

In the current study, Zn fertilization significantly improved LAI. Despite recording low LAI values on 30 and 50 DAS, lathyrus showed a rapid response to foliar nutrition, as evident from significantly higher LAI values (1.46-1.74) in Zn_5 and Zn_6 on 70 and 90 DAS. This indicates that in the case of foliar feeding, a quicker response to the applied nutrient can induce favourable canopy adjustment in lathyrus in Zn-deficient soils.

Root and shoot dry weight

D_2 recorded significantly higher root weight than D_1 on 30 and 50 DAS, while no significant difference was observed between them during later stages of crop growth (Table 2). However, in the case of shoot biomass, D_2 recorded significantly higher values throughout the crop life. Exposure to a congenial thermal regime, especially during the first 30 DAS (25.3°C in 2018-19 and 25.2°C in 2019-20) possibly improved root and foliar growth in D_2. The initial boost in vegetative growth might have helped the D-$_2$ sown crop to sustain a favourable biomass accumulation even when exposed to high maximum temperatures (>27.0°C) in the reproductive stage. Sehgal *et al.* (2018) reported that, due to their efficient thermo-tolerance capacity, leaves exhibit high resilience at reproductive ceiling temperatures.

Zn_1 (control) recorded the highest root dry weight but the lowest shoot weight. The soil at the current experimental site had low (0.54 ppm) DTPA-extractable Zn. It is likely that in the Zn_1 treatment, where no Zn was applied, the crop developed a vigorous root system at the cost of shoot biomass to explore a larger volume of soil to acquire Zn. Yang *et al.* (2011) also reported that Zn deficiency augmented root growth in wheat. On the contrary, soil fertilization with 25 kg $ZnSO_4$ ha^{-1} recorded significantly lower root weight than other levels of soil fertilization on 70 and 90 DAS but significantly higher shoot weight during the

Table 1: Effect of sowing dates and Zn nutrition on plant height (cm) and leaf are index of lathyrus.

Treatments	Plant height (cm)				Leaf area index			
	30 DAS	50 DAS	70 DAS	90 DAS	30 DAS	50 DAS	70 DAS	90 DAS
Date of sowing								
D1	29.6b	66.1b	86.2b	106.8b	0.37b	0.82a	1.35b	1.57b
D2	30.5a	69.0a	89.4a	110.6a	0.39a	0.74b	1.43a	1.65a
Zn nutrition								
Zn1	27.1ef	54.0e	89.8c	95.6d	0.27e	0.50f	1.16e	1.35f
Zn2	28.8de	65.2cd	90.3a	110.2a	0.39d	0.76d	1.31d	1.57de
Zn3	31.5bc	69.4bc	92.0a	111.5a	0.43c	0.84bc	1.4bc	1.68abc
Zn4	36.7a	75.6a	92.7a	110.6a	0.52a	1.02a	1.52a	1.65bcd
Zn5	26.8f	60.3d	86.3b	107.6ab	0.27e	0.7e	1.46ab	1.62bcd
Zn6	27.0f	62.4d	85.7b	109.0ab	0.29e	0.73de	1.48ab	1.74ab
Zn7	32.2b	71.9ab	90.1a	105.4b	0.47b	0.88b	1.41bc	1.51e
Zn8	30.38cd	69.42bc	89.23a	104.72b	0.43c	0.81c	1.36cd	1.5e

Within sowing dates and Zn nutrition, numbers followed by different letters are significantly different at $p \leq 0.05$. ¥ DAS-days after sowing.

growing period. The addition of Zn fertilizer to the soil increases DTPA-Zn in the upper soil layer (Liu *et al.,* 2019). This supports sufficient Zn absorption to meet the crop's physiological needs from the upper layer itself, with no need for a robust root system to capture Zn from the deeper soil layer. Foliar nutrition recorded significantly lower root weight during crop life but showed significant improvement in shoot growth after Zn application, as observed on 70 and 90 DAS. Zn supplementation through foliar fertilization might have met the Zn demand of the crop by maintaining a favourable plant Zn status, ultimately resulting in enhanced shoot growth (Ahmed *et al.,* 2023). This possibly also acted as a signal to offset the need to capture Zn from the soil, which, when perceived by the root, limited its growth.

Crop growth rate (CGR)

The crop exhibited early slow growth (30-50 DAS), followed by rapid growth during the late vegetative and early flowering stages (50-70 DAS) (Fig 2). CGR then showed a sharp decline during the late flowering and pod development stages (70 -90 DAS). The dip in overall CGR during 70-90 DAS might be because of the diversion of current assimilates more towards pod formation and filling than vegetative growth. The late sown crop recorded a significantly higher CGR during 30-70 DAS. Despite the D$_2$ sown crop being subjected to high temperatures during 70-90 DAS, no significant difference in CGR between the two dates of sowing was seen. An early head start in TDM production and LAI due to a favourable thermal regime in the early stages may have helped the D$_2$ sown crop sustain a higher CGR even while experiencing high maximum temperatures (27.3 and 27.7°C) during 70-90 DAS. Although the threshold heat stress temperature of the lathyrus has not been specifically reported, it is capable of withstanding extreme temperatures (Dixit *et al.,* 2016). Likewise, significant improvements in TDM accumulation and LAI of lathyrus in response to Zn nutrition were reflected in increased CGR. For instance, favourable canopy adjustment as an immediate response to foliar Zn nutrition resulted in improved biomass accumulation and significantly increased CGR (5.43 g m^{-2} day^{-1}) in Zn$_6$ during 50-70 DAS.

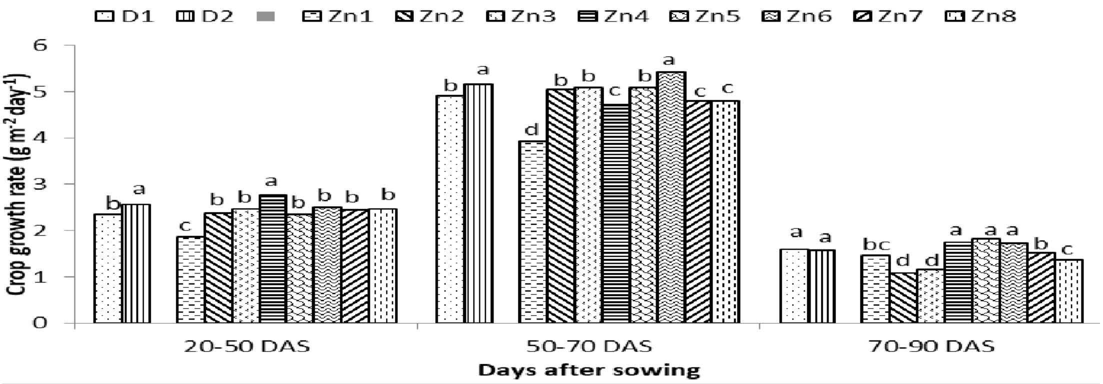
Yield attributes, yield, grain and straw Zn content and economics

The late sown crop (D$_2$) recorded significantly higher pods plant^{-1} (24), 100 seed weight (7.40 g), harvest index (0.40)

Table 2: Effect of sowing dates and Zn nutrition on root and shoot weights (g m^{-2}) of lathyrus.

Treatments	Root weight (g m^{-2})				Shoot weight (g m^{-2})			
	30 DAS	50 DAS	70 DAS	90 DAS	30 DAS	50 DAS	70 DAS	90 DAS
Date of sowing								
D1	6.04b	11.11b	20.04a	20.93a	20.49b	62.73b	152.2b	183.14b
D2	6.27a	13.69a	19.43a	20.32a	22.19a	65.97a	163.35a	194.14a
Zn nutrition								
Zn1	5.07e	11.74ab	24.37a	28.89a	10.15g	40.81f	106.79d	131.56e
Zn2	5.69d	12.08a	21.96b	24.89b	17.77f	58.78e	149.9c	168.78d
Zn3	7.49a	12.12a	21.22b	23.26c	23.37c	68.05bc	160.65b	181.71c
Zn4	7.64a	11.47b	18.16d	19.13f	28.88a	80.5a	168.4a	202.29a
Zn5	5.22e	10.14c	16.68e	18.05g	21.25e	63.52d	158.64b	193.76b
Zn6	5.18e	10.52c	16.32e	18.25fg	21.56de	66.27cd	169.08a	201.65a
Zn7	6.90b	11.25b	19.42c	20.01e	25.29b	70.16b	158.23b	188.29b
Zn8	6.10c	11.43b	19.76c	21.55d	22.47cd	66.71c	154.52bc	180.04c

Within sowing dates and Zn nutrition, numbers followed by different letters are significantly different at p≤0.05. ¥ DAS-days after sowing.



Columns for sowing dates and columns for Zn nutrition with different grouping letter are significantly different at p≤0.05

Fig 2: Effect of sowing dates and Zn nutrition on crop growth rate (g m^{-2} day^{-1}) of lathyrus.

Table 3: Effect of sowing dates and Zn nutrition on yield, yield attributes and Zn concentration of lathyrus.

Treatments	Seed Yield (kg ha^{-1})	Pods plant^{-1}	100-seed weight (g)	Harvest index	Grain Zn (ppm)	Stover Zn (ppm)
Date of sowing						
D1	1198b	21.3b	6.95b	0.38b	28.28a	39.05a
D2	1380a	24.0a	7.40a	0.40a	27.58a	38.41a
Zn nutrition						
Zn1	886e	17.8c	6.06c	0.35e	22.84e	33.05d
Zn2	1124de	20.2b	6.83b	0.38cd	25.77d	36.40c
Zn3	1196d	21.9b	6.95b	0.39bcd	27.61c	38.71b
Zn4	1407bc	25.7a	7.64a	0.41ab	29.10ab	40.37ab
Zn5	1512ab	25.6a	7.87a	0.41abc	28.30bc	38.86ab
Zn6	1647a	27.5a	7.93a	0.43a	30.36a	40.89a
Zn7	1251cd	21.7b	7.17b	0.39bc	27.33c	38.46b
Zn8	1190d	21.0b	6.97b	0.38cd	28.38bc	39.42ab

Within sowing dates and Zn nutrition, numbers followed by different letters are significantly different at $p \leq 0.05$. ¥ DAS-days after sowing.

Table 4: Effect of sowing dates and Zn nutrition on economics of lathyrus.

Treatments	Cost of cultivation (Rs. ha^{-1}) (COC)	Gross return(Rs. ha^{-1}) (GR)		Net return (Rs. ha^{-1})		GR:COC	
		D1	D2	D1	D2	D1	D2
Zn1	34738	36733	38515	1995	1783	1.06	1.11
Zn2	36978	40434	45333	3456	4898	1.09	1.23
Zn3	37714	43316	48318	5602	5002	1.15	1.28
Zn4	38472	48355	58289	9883	9934	1.26	1.52
Zn5	36836	51309	63085	14474	11776	1.39	1.71
Zn6	37583	58796	66480	21214	7684	1.56	1.77
Zn7	35695	43729	51463	8034	7734	1.23	1.44
Zn8	36315	40919	47615	4604	6697	1.13	1.31

and yield (1380 kg ha^{-1}) than the early sown crop due to overall improved crop growth favoured by congenial weather conditions (Table 3). Foliar nutrition with Zn, irrespective of doses, was observed to be more effective than soil fertilization in improving yield (1512-1647 kg ha^{-1}). Therefore, growing conditions (Tzudir *et al.* 2016) and Zn management (Kumar *et al.,* 2016) favouring improved biomass accumulation, growth rates and partitioning of assimilates to sink in lathyrus are likely to fare well in terms of productivity.

Interestingly, the dates of sowing exerted no significant influence on grain and stover Zn content (Table 3). Domingos and Bilsborrow (2021) also observed no significant influence of sowing conditions on Fe and Zn content in buckwheat. Basal application of 25 kg $ZnSO_4$ ha^{-1} and 1.0 % $ZnSO_4$ foliar spray at pre-flowering and pod initiation stages recorded significantly higher grain Zn (29.10- 30.36 ppm) and stover Zn (40.37- 40.89 ppm) content. The higher Zn content in these two treatments was likely due to improved assimilation and absorption of the applied nutrient, which enhanced crop growth and produced Zn-enriched seeds (Dhaliwal *et al.,* 2021).

The D_2 sown crop recorded a 15.0% higher gross return (GR) and GR: COC ratio than D_1 due to the crop's better yield performance (Table 4). Foliar nutrition with 1.0% $ZnSO_4$ fetched maximum gross return (Rs. 62638 ha^{-1}) and GR: COC ratio (1.67) closely followed by foliar nutrition with 0.5% $ZnSO_4$, thereby making them feasible agronomic interventions for resource-poor farmers.

CONCLUSION

Exposure to a lower thermal regime in the early stages improves vegetative growth in late-sown (29 November) lathyrus, which might help the crop sustain adequate biomass accumulation and yield even when subjected to high temperatures later in crop life. Improved absorption and assimilation of the applied Zn with foliar fertilization of 1.0% $ZnSO_4$ at pre-flowering and pod development stages resulted in lathyrus yield intensification and the production of Zn-dense seed and stover. Striking a balance between root and shoot growth under suboptimal conditions is likely a crucial determinant of final yield in lathyrus. Hence, lathyrus can be conveniently accommodated with adequate foliar Zn nutrition in Zn-deficient rice-based systems of the lower

Gangetic plains, where delayed sowing and short winters adversely affect the growth of post-rice crops.

ACKNOWLEDGEMENT

The authors duly acknowledge AICRP-MULLaRP, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, for supporting this study.

Conflict of Interest: None.

REFERENCES

Ahmed, R., Uddin, M.K., Quddus, M.A., Samad, M.Y.A., Hossain, M.M. and Haque, A.N.A. (2023). Impact of foliar application of zinc and zinc oxide nanoparticles on growth, yield, nutrient uptake and quality of tomato. Horticulturae. 9(2): 162.

Chaudhary, M., Mandal, A., Muduli, S., Deepasree, A. (2022). Agronomic biofortification of food crops: A sustainable way to boost nutritional security. Revisiting Plant Biostimulants. IntechOpen.

Dhaliwal, S.S., Sharma, V., Shukla, A.K., Kaur, J., Verma, V., Singh, P., Singh, H., Abdel-Hafez, S.H., Sayed, S., Gaber, A. and Ali, R., (2021). Enrichment of zinc and iron micronutrients in lentil (*Lens culinaris* Medik.) through biofortification. Molecules. 26(24): 7671.

Dixit, G.P., Parihar, A.K., Bohra, A. and Singh, N.P. (2016). Achievements and prospects of grass pea (*Lathyrus sativus* L.) improvement for sustainable food production. The Crop Journal. 4(5): 407-416.

Domingos, I.F. and Bilsborrow, P.E. (2021). The effect of variety and sowing date on the growth, development, yield and quality of common buckwheat (*Fagopyrum esculentum* Moench). European Journal of Agronomy. 126: 126264.

Kumar, R., Rathore, D. K., Singh, M., Kumar, P. and Khippal, A. (2016). Effect of phosphorus and zinc nutrition on growth and yield of fodder cowpea. Legume Research-An International Journal. 39(2): 262-267.

Liu, D. Y., Liu, Y. M., Zhang, W., Chen, X. P. and Zou, C. Q. (2019). Zinc uptake, translocation and remobilization in winter wheat as affected by soil application of Zn fertilizer. Frontiers in plant science. 10: 426.

Maji, S., Das, A., Nath, R., Bandopadhyay, P., Das, R. and Gupta, S. (2019). Cool Season Food Legumes in Rice Fallows: An Indian Perspective. Agronomic Crops: Production Technologies, Springer. 1: 561-605.

Sehgal, A., Sita, K., Siddique, K.H., Kumar, R., Bhogireddy, S., Varshney, R.K., HanumanthaRao, B., Nair, R.M., Prasad, P.V. and Nayyar, H. (2018). Drought or/and heat-stress effects on seed filling in food crops: impacts on functional biochemistry, seed yields and nutritional quality. Frontiers in Plant Science. 9: 1705.

Tesfaye, K., Walker, S. and Tsubo, M. (2006). Radiation interception and radiation use efficiency of three grain legumes under water deficit conditions in a semi-arid environment. European journal of Agronomy. 25(1): 60-70.

Tzudir, L., Basu, S., Maji, S., Bera, P.S., Nath, R., Mazumdar, D. and Chakraborty, P.K. (2016). Impact of weather variables on dry matter accumulation and yield of mungbean [*Vigna radiata* (L.) Wilczek] varieties under different dates of sowing. Legume Research-An International Journal. 39(3): 427-434.

Wahid, A., Gelani, S., Ashraf, M. and Foolad, M. R. (2007). Heat tolerance in plants: An overview. Environmental and Experimental Botany. 61(3): 199-223.

Yang, X.W., Tian, X.H., Lu, X.C., Cao, Y.X. and Chen, Z.H. (2011). Impacts of phosphorus and zinc levels on phosphorus and zinc nutrition and phytic acid concentration in wheat (*Triticum aestivum* L.). Journal of the Science of Food and Agriculture. 91(13): 2322-2328.