Fight Against Hidden Hunger: Boosting Zincin Potato through Biofortification in Calcareous Soil of Bihar

Abstract

To improve the nutrient status of Zinc in potato, this research was conducted in the *Rabi* period of 2022-2023 at TCA-Dholi,Dr. RPCAU, Pusa,Bihar. Experimental material comprised of popular local variety, *Kufri Khyati*, with ten treatments and was replicated four times, using Randomized Block Design (RBD). Crop received varied level and forms of Zinc, and SPAD meter reading was taken at different stages of crop growth. The maximum concentration of Zinc in leaves at 65 DAP and in tubers at harvest were, 95.45 ppm and 31.50 ppm respectively; maximum SPAD meter readingof 49.29, 42.04, 37.11 at 45 DAP, 60 DAP and 75 DAP respectively; maximum yield of 25.17 t $ha^{-1}$and highest B:C ratio of 2.97with $T_{10}$where chelated Zinc-EDTA @ 4g $litre^{-1}$ at 25 and 50 DAP was applied, whereas, $T_7$with soil application of 12.5 kg ha^{-1}along with foliar application of $ZincSO_4$ @ 2 g $litre^{-1}$ at 25 DAP and 50 DAP, and $T_6$with soil application of 12.5 kg ha^{-1}along with foliage application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25DAP, comparable to the treatment T_{10}.

Keywords: Agronomic, Biofortification, SPAD meter, Zinc

Introduction

The botanical name for the potato is *Solanum tuberosum*, belonging to the Solanaceae family, known as the "nightshade" family. It is a member of the section Petota of the genus Solanum. There are two subspecies of *Solanumtuberosum:*andigena, which is suited to short-day conditions, and tuberosum, which is currently grown all over the world.Potato is one of the most important crops after rice and wheat in world, and in India it is mainly grown in the states of Himachal Pradesh, Punjab, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, West Bengal, Bihar, and Assam, with cultivated area of 2.05 mha. In Bihar, the cultivation area is 0.32 mha, with production of 5.75 million tonnes. Bihar lacks in productivity as compared to national average of 23.68 t/ha, with productivity of 17.93 t/ha.

Biofortification is an approach for increasing the concentration of certain micronutrients, such as Zinc, in food crops by the application of agronomic, or genetic, techniques. Consuming staple foods that have been biofortified would improve the adequacy of Zinc intake for those whose intakes are insufficient.Crops are affected, productivity is severely decreased due to low Zinc content in mostagricultural soils, and problems with public health develops over time. Although it is only required in minimal amounts, Zinc plays a significant role in many metabolic processes, including the activation of enzymes, the synthesis of proteins and carbohydrates, DNA replication, RNA transcription, and chromatin structure. Zinc is important for human health. However, more than 33% of the world's population suffers from deficiency of Zinc, which raises the danger of problems including infectious diseases, DNA damage, delayed development, and immuno-incompetence in people.

The most recent catastrophe was COVID-19, which was due to the SARS-CoV-2 coronavirus.It is widely known fact that Zinc has a range of antiviral activities that are accomplished through several ways. Zinc supplementation may boost innate and humoral antiviral immunity, repair impaired immune cell function, or promote healthy immune cell activity, especially in immunosuppressed or older individuals. As found in individuals with hepatitis C and SARS-CoV-1, Zinc may potentially function in a synergistic way when used with the common antiviral medication. Zinc also shields the cell membrane, which might help prevent a virus from entering the cell. As a result, it is conceivable that Zinc supplementation might be advantageous for the cure of COVID-19**.** (Kumar *et al.* 2020)

In Bihar region, currently a limited amount of data and knowledge on the agronomic biofortification of potatoes is available. This research will assist to determine the possibilities of Zinc biofortification of potatoes.Limited availability of essential micronutrients in Bihar soil due to poor organic content in soil, high pH, and $CaCO_3$ content, which leads to Fe, Mn, and Zincdeficiency. Concerning the nutritious value of potatoes, it is to prioritise biofortification as a key job for potato valorisation.

Materials and Methods

Experimental Site

The research was conducted in*Rabi*season of 2022-23 at TCA, Dholi, Dr. RPCAU, Bihar. The experimental location is located at 25 degrees 98-minutes, North (N) latitude and 85 degrees 60-minutes, East (E) longitude nearby*BurhiGandak*, a tributary of Gandak river, at an elevation of 52.2 m ASL. The soil was calcareous-alluvium and somewhat alkaline as a result of sediment deposition by the BurhiGandak River. Across the depth of the soil profile, the sediment from Gandak often includes a high proportion of free CaCO3, ranging from 10 to 45 percent.

Climatic Conditions

The experimental site comes under a sub-humid, subtropical climatic condition with modest rainfall, hot dry summer, and cold winter.During the crop season, the least and maximum temperatures recorded were ranged from 7.6°C to 18.70°C and 16.4°C to 30.6°C, respectively. The highest and lowest RH (%) of the experimental area ranged between 91.8 and 66.7% respectively, during the crop season (2022-23).

Treatment Details

The treatments were kept, considering the prevalent practices among farmers, along with some novel method of application, which are not that much popular, in the areas of Muzaffarpur and its surroundings.

T_1- Control;**T_2**-$ZnSO_4$ @ 12.5 kg ha^{-1}incorporated in soil at planting; **T_3**- $ZnSO_4$ @ 25 kg ha^{-1}soil incorporated at planting; **T_4-** $ZnSO_4$ @ 2g $litre^{-1}$foliar application at 25 DAP; **T_5-** $ZnSO_4$ @ 2g $litre^{-1}$ foliar application at 25 and 50 DAP; **T_6-** T_2 + $ZnSO_4$ @ 2g $litre^{-1}$foliar application at 25 DAP; **T_7**- T_2 + $ZnSO_4$ @ 2g $litre^{-1}$ foliar application at 25 and 50 DAP; **T_8-** ZnO tuber treatment for 12 hours, before planting; **T_9-** Chelated Zinc @ 4 g $litre^{-1}$ at 25 DAP; **T_{10}-** Chelated Zinc @ 4 g $litre^{-1}$ at 25 and 50 DAP.

The study trial was conducted using a randomized-block design (RBD) withfour number of replications, using a net plot of 10 for each replication,and a gross plot of 40. Gross plot size was 4.8 × 4.0 (m), and net plot size was 3.6 × 3.6 (m), with a spacing of 60 × 20 (cm), and the recommended of fertilizer, which was applied in all treatments for NPK was 150:90:100.

SPAD meter reading and chemical analysis with AAS

The SPAD metre calculates SPAD value by comparing the red (650 nm) and infrared (940 nm) light transmittance through the leaf.The contents of chlorophyll reflect leaf photosynthesis ability and plant health condition.Early in the morning and late at night, 20–30 samples from each treatment were used to measure the SPAD value of fully opened topmost leaves.

An analytical method called the AAS (Atomic Absorption Spectrophotometer) is employed to determine the concentration of a certain element in a sample.Plant samples were collected from the treated plots and oven-dried in hot air oven for 24 hours followed by grinding in mortar and pestle. The grinded samples were mixed with di-acid solution of Sulphuric Acid and Nitric Acid in the ratio of 4:1, and then put onto Hot-Plate apparatus for uniform and flame-less heating of the samples. The mixture of samples with di-acid was reduced, and the final volume obtained was 5 ml, for every sample. Analysis in the AAS (Atomic Absorption Spectrophotometer) was used to determine the Zinc content in the samples.

Results and Discussion

SPAD meter reading of leaves

There was significant difference among treated plots and control (given in table 1). SPAD meter reading of leaves were recorded at 45, 60 and 75 DAP**.** Significant difference was observed between the Zinc treated and control plot, where control plot i.e., T_1 had minimum SPAD reading of 43.98, whereas T_{10} had the maximum reading of 49.29 at 45 DAP. At 60 DAP, the maximum reading was observed in T_{10} of 42.04, while treatment T_1 (Control) showed minimum value of 37.98. At 75 DAP, the maximum value was recorded in T_{10} of 37.11.The increased chlorophyll content is due to Zn, a co-factor for the normal functioning of pigment biosynthesis as well as a structural and catalytic component of proteins and enzymes. (Balashouri, 1995). This finding was similar with observations represented by Samreen et al. (2017), in mungbean crop.

Zinc concentration in soil before and at harvest

No significant differences were among treatment before sowing of crop, whereas at harvest significant differences were among treatments, due tovarious Zinc fertilizer application, where T_3 had highest Zinc of 0.76 ppm, while lowest was in T_1 Control (No Zinc) with 0.43 ppm, a striking distinction among the foliar application technique of Zn fertilisation and the soil application approach. $ZnSO_4$ soil applicationwas generally most effective nutrient management technique for increasing soil Zn concentration. The results are quite similar to those that were reported by Durgude*et al*. (2014), Behera *et al*. (2008).

Zinc concentration in leaves at 65 DAP (ppm)

Treatments had different concentrations in leaves at 65 DAP, due to various Zn fertilization sources, where T_{10} (Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP) had significantly highest amount of Zn concentration of 95.45 ppm, while control plot had 49.69 ppm of Zn concentrations, whereas T_5 and T_9 with concentration of 93.32 and 89.99 ppm, respectively were statistically at par with treatment T_{10}.

Zinc concentration in tubers at harvest (ppm).

T_{10} (Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP) had maximum concentration of Zn in tubers of 31.50 ppm, whereas T_3, T_5 and T_9 had concentrations of 30.80, 30.80 and 29.70 ppm, were statistically at par with T_{10}as shown in fig 1.Similar findings were observed by Lerna *et al*. (2020) and White *et al*. (2012) in potato crop, where foliar Zn treatment led to higher Zn content in the leaves and tubers.

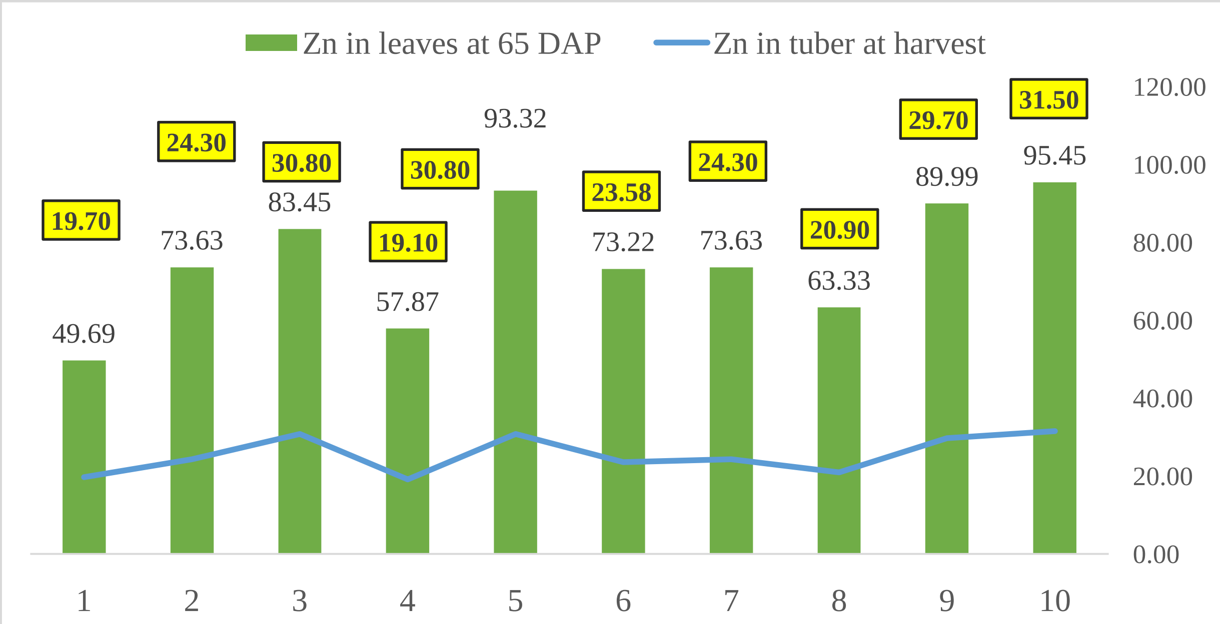

Fig 1. Zinc concentration in leaves at 65 DAP andin tubers at harvest (ppm)

Benefit Cost ratio

Among all treatments, T_{10} had maximum B:C of 2.97, while T_8had minimum benefit cost ratio of 2.05, while T_3,T_5,T_6, T_7 and T_9were statistically at par with T_{10}. The highest B:C ratio, was obtained with foliar spray of chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP, which was similar to the findings of Naik and Das (2007), in rice.

Total yield of tubers (in t ha^{-1})

Zinc fertilization had a substantial impact on the yield in different treatments (given in fig. 2), with T_{10} having the most significant yield of 25.17 t/ha and T_1 having the lowest of 20.88 t/ha, while T_2, T_3, T_5, T_6, T_7, and T_9were statistically equal to T_{10} in terms of yield.The effect that Zn plays in carbohydrate metabolism may be the most significant factor contributing to the increase in tuber yield caused by Zn intake.The result was similar to that of Namini *et al*. (2021)

Haulm yield (in t ha^{-1})

T_{10} statistically had the highest haulm yield of 11.41 t/ha (given in fig. 2), among treatments, whereas T_1 (Control) had the lowest yield of 9.55 t/ha. Treatments T_2, T_3, T_5, T_6, T_7, and T_9were statistically equal to treatment T_{10} in this regard. Higher harvest yield may have resulted from a significant increase in growth and yield-related traits like plant height and number of tubers per plant. These results were consistent with the observations and conclusions of Chaudhary *et al*. (2019).

Harvest Index (H.I in %)

Although the H.I was non-significant (given in fig. 2), it was found that T_6 had the highest harvest index of 69.67 % and T_5 had the lowest of 67.91 %.This might be due to the higher photosynthetic rate during the tuberization period and partitioning of photosynthates to sink. This result was supported by Nag (2006) and Patel (2013).

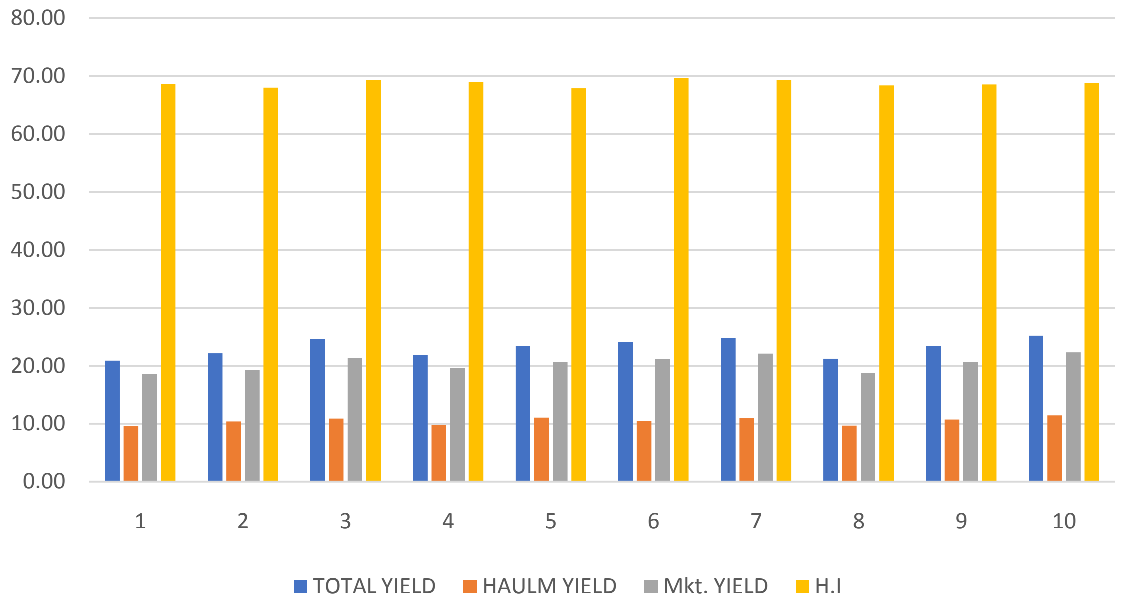

Fig 2. Total yield, haulm yield, marketable yield, and harvest index (H.I)

Physical and chemical properties of soil before sowing and after harvesting

There were no statistical differences among pH, EC (dS m^{-1}), OrganicCarbon (%) and $CaCO_3$(%)of various treatments, before sowing and after harvest of potato crop, this result is in accordance with Gajbhiye*et al*. (2018) and Keram *et al*. (2012), where they found the similar findings in maize and wheat, respectively.

Table 1: SPAD meter reading of leaves at 45, 60 and 75 DAP

S.no.	Treatment Details	45 DAP	60 DAP	75 DAP
T_1	Control (No Zn)	43.98	37.98	31.73
T_2	$ZnSO_4$ @ 12.5 kg ha^{-1} at the time of planting (soil)	46.98	40.33	34.19
T_3	$ZnSO_4$ @ 25 kg ha^{-1} at the time of planting (soil)	48.65	41.78	36.17
T_4	$ZnSO_4$ @ 2 g $liter^{-1}$ at 25 DAP (foliar)	45.52	38.87	32.35
T_5	$ZnSO_4$ @ 2 g $liter^{-1}$ at 25 and 50 DAP (foliar)	47.96	41.65	35.34
T_6	T_2 + $ZnSO_4$ @ 2 g $liter^{-1}$ at 25 DAP (foliar)	47.04	40.28	34.79
T_7	T_2 + $ZnSO_4$ @ 2 g $liter^{-1}$ at 25 and 50 DAP (foliar)	47.05	40.40	34.45
T_8	ZnO (4%) tuber treatment for 12 hours, before planting	45.84	39.22	33.06
T_9	Chelated Zn foliar application @ 4 g $liter^{-1}$ at 25 DAP	47.28	40.61	34.93
T_{10}	Chelated Zn foliar application @ 4 g $liter^{-1}$ at 25 and 50 DAP	49.29	42.04	37.11
SEm (±)		1.65	1.42	1.20
LSD (*p*=0.05)		4.80	4.12	3.49

Table 2: Available Zn before sowing and after harvest (ppm)

S.no.	Treatment Details	Before Sowing	After Harvest
T_1	Control (No Zn)	0.48	0.43
T_2	$ZnSO_4$ @ 12.5 kg ha^{-1} at the time of planting (soil)	0.46	0.64
T_3	$ZnSO_4$ @ 25 kg ha^{-1} at the time of planting (soil)	0.44	0.76
T_4	$ZnSO_4$ @ 2 g $liter^{-1}$ at 25 DAP (foliar)	0.45	0.49
T_5	$ZnSO_4$ @ 2 g $liter^{-1}$ at 25 and 50 DAP (foliar)	0.43	0.52
T_6	T_2 + $ZnSO_4$ @ 2 g $liter^{-1}$ at 25 DAP (foliar)	0.45	0.67
T_7	T_2 + $ZnSO_4$ @ 2 g $liter^{-1}$ at 25 and 50 DAP (foliar)	0.49	0.7
T_8	ZnO (4%) tuber treatment for 12 hours, before planting	0.42	0.46
T_9	Chelated Zn foliar application @ 4 g $liter^{-1}$ at 25 DAP	0.44	0.46

T_{10}	**Chelated Zn foliar application @ 4 g liter^{-1} at 25 and 50 DAP**	**0.43**	**0.47**
	SEm (±)	**0.02**	**0.02**
	LSD (*p*=0.05)	**0.05**	**0.06**

Discussion

The Zinc content in treated plots was considerably high as compared to control plot, with T_{10} showing 62% more biofortification of Zinc mineral than control. This research showed that Zinc content in potato tubers can be considerably increased through Zinc fertilizers, although one more study could be done, of, how much Zinc remains after cooking of the potato.

Zinc, a co-factor for the proper functioning of pigment biosynthesis as well as component of proteins and enzymes, is responsible for the increased chlorophyll concentration, as determined from the SPAD metre value reading.

The increase in tuber production caused on by Zinc supplementation may be primarily attributed to the function Zinc performs in carbohydrate metabolism.Zinc enhances the concentration of starch and glucose in plant tissue, that will enhance production, by contributing to the production of carboxyl phosphate and RNA polymerase enzymes.Zinc helps plants develop vegetatively and increases their capacity for photosynthesis. These improvements allow for improved translocation of synthesized materials throughout the plant, which boosts overall growth and growth characteristics. Zinc has a stimulating effect on vegetative growth and may have an impact on the productive section (tuber), which might account for its influence on yield-related factors.

Due to higher absorptivity brought on by chelating agents, chelated Zinc was better retained in leaves. Zinc absorption is affected by phosphorus, but chelated Zinc performed better in presence of phosphorus. The increase in Zinc concentration might be explained by the significantly greater amount of Zinc absorption seen with Zinc-EDTA treatment compared to $ZnSO_4$ application. Additionally, Zinc-EDTA was more effective in mobilising Zinc than $ZnSO_4$ for crop absorption. Therefore, biofortification of Zinc was more in treatments, where chelated Zinc was used, as compared to plots having application of $ZnSO_{4,}$either through soil or foliar.

Conclusions

Potato being one of the most important and widely consumed vegetable, is often ignored with respect to its nutrition content. Biofortification of potato, would not only enhance the nutritivevalue of potato, but also the boost health and immunity of the people at grass root level. Application of Zinc would enhance the growth and development of the crop, fertility status of soil and enhanced efficiency of other applied fertilizers, thus, giving higher economic returns.

- The maximum concentration of Zn in leaves at 65 DAP and in tubers at harvest, were 95.45 ppm and 31.50 ppm respectively, found in $\mathbf{T_{10}}$where chelated Zn-EDTA was applied @ 4 g litre^{-1} at 25 and 50 DAP.
- The best B:C ratio was obtained by $\mathbf{T_{10}}$having application of chelated Zn-EDTA @ 4g litre^{-1} at 25 and 50 DAP.
- The maximum SPAD reading was observed in T_{10} (Chelated Zn @ 4 g liter$^{\mathbf{-1}}$ at 25 and 50 DAP), of 42.04, while treatment T_1 (Control) showed minimum value of 37.98at 60 DAP.

Recommendations

This experimental conclusion was based on one-year investigation. Performing this experiment for more than three years continuously will provide a solid conclusion on the response of distinct sources of Zinc fertilizers, in biofortification of potato, and on growth and production of potato crop. Although based on one year result, recommendation may be givenof Chelated Zinc @ 4g per litre, with two-times application, one at 25 DAP and the another one at 50 DAP, to farmers and potato growers, with aim to improve zinc status of potato.

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