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Response of agronomic biofortification of zinc with different application methods on growth and yield of potato

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Abstract
A field experiment was conducted during the *Rabi* season of 2021-2022 at the Research Field of TCA, Dholi, a uni-campus of RPCAU, Pusa, Bihar, India to study the identification of suitable zinc application method for agronomic biofortification on growth and yield of Potato crop**.** The treatment consisted of ten different methods of application with different time of application of zinc, *viz*., T1 Control (No Zn), T2 (Soil incorporation of $ZnSO_4$ @ 12.5 kg ha^{-1}) at the time of planting, T3 (Soil incorporation of $ZnSO_4$ @ 25 kg ha^{-1} at the time of planting), T4 (Foliar application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25 days after planting), T5 (Foliar application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25 and 50 days after planting), T6 (T6 + foliar application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25 days after planting), T7 (T2 + foliar application of ZnSO4 @ 2 g $litre^{-1}$ at 25 and 50 days after planting), T8 (Tuber treatment with ZnO for 12 hours, before planting), T9 (Chelated Zn @ 4 g $litre^{-1}$ at 25 days after planting), T10 (Chelated Zn @ 4 g $litre^{-1}$ at 25 and 50 days after planting). The higher growth, yield (25.17 t ha^{-1}) and B:C ratio was obtained with T10, which included the application of chelated Zn-EDTA @ 4 g $litre^{-1}$ at 25 and 50 DAP, whereas T7 having soil application of 12.5 kg ha^{-1} foliar application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25 and 50 days after planting, and T6 having soil application of 12.5 kg ha^{-1} foliar application of $ZnSO_4$ @ 2 g $litre^{-1}$ at 25 days after planting, were at par with treatment T10.

Keywords: Application methods, biofortification, growth parameters, potato, and yield, zinc

Introduction

The Potato, *Solanum tuberosum* in its scientific name, is a member of the Solanaceae family, sometimes referred to as the "nightshade" family. *Solanum tuberosum* is a herbaceous perennial that may reach a height of approximately 1 m has long, pinnate leaves, has pink, white, purple, or blue flowers with stamen of yellow colour, and produces fruit that resembles a green cherry tomato but is deadly to humans owing to the presence of solanine, an alkaloid. The growing potato plant generates bigger subterranean stems, sometimes known as tubers, which are a valuable economic component. (Anonymous, 2011) [1].

Most of the potato crop is propagated by vegetative parts, i.e., tubers, which are clones of their parent. At the same time, seed-grown plants show wide variations, with poor vigour and lower yields. More propagation from seeds is a time-consuming and labour-intensive process. Hence, propagation from tubers is preferred over seeds in potato crop. Potatoes are the third-largest major food crop in terms of human consumption, after rice and wheat. 300 million metric tonnes of agricultural products are produced globally, and more than one billion people eat potatoes. Potatoes are a low-fat, low-calorie carbohydrate option that contains one-fourth of bread calories. 'Potato, has a nutrient constituent of Carbohydrate 20.13 g, Protein 1.87 g, Fibre 1.8 g, Fat 0.1 g, Potassium 379 mg, Phosphorus 44 mg, Vitamin C 13 mg, Fe 0.4 mg, Zn 0.3 mg, Calcium 5 mg, Riboflavin 0.02 mg, Thiamine 0.10 mg, Niacin 1.44 mg' (Anonymous, 2011) [1].

The technique of biofortification involves giving staple crops direct access to the daily micronutrients. With the use of agronomic or genetic methods, biofortification is an intervention technique currently under research to boost the amount of certain micronutrients, such as Zn, in the edible section of food crops. For people with high rates of insufficient intakes, consuming biofortified staple foods would result in better adequate Zn intake and, thus, a decreased risk of dietary Zn insufficiency. Biofortification is one of the most cost-effective techniques for combating global nutrient deficiency.

Biofortification aims to improve the micronutrient content and increase the nutrient bioavailability in the edible parts of staple crops. Using agronomic methods, traditional plant breeding, and biotechnology, this strategy for providing micronutrients to people experiencing poverty in developing nations entails making the basic foods they eat more nutritious.

The low Zn concentration in most agricultural soils affects crops, so production is significantly reduced, and public health issues arise. Zn is crucial for human health; although it is only needed in trace amounts, it is necessary for several critical metabolic functions, including activating enzymes, synthesising proteins and carbohydrates, DNA replication, RNA transcription, and chromatin structure. However, Zn deficiency affects over 1/3rd of the world's population, which increases the risk of infectious illnesses, DNA damage, stunted development, and immuno-incompetence in individuals. Only a small portion of the Zn in meals ingested by people is accessible and easily absorbed by the digestive system. In addition to having outstanding digestibility and being a very prolific crop consumed by most people worldwide, potatoes also offer significant potential for agronomic biofortification. The poor movement of this element in the phloem and the adsorption of Zn to the soil components make it difficult to improve the Zn content in tubers. The Zn biofortification of tubers might successfully improve the Zn concentration in potato tubers and its bioavailability for people. To date, limited data and information are available, in the Bihar region, for agronomic biofortification of Potato, and this research work will help in knowing the potential of Zn biofortification of Potato, in the local popular cultivated variety, *Kufri Khyati.*

Materials and Methods

The field experiment was carried out during the *Rabi* period of 2021-2022 at the Research Field of TCA, Dholi (Muzaffarpur), a sub-campus of RPCAU, Pusa (Samastipur), Bihar, India, located at 25º98' North (N) latitude and 85º60' East (E) longitude on the southern bank of the river *Burhi Gandak*, at an elevation of 52.2 m above mean sea level. It enjoys a humid sub-humid and sub-tropical climate, influenced greatly by the southwest monsoon. The main characteristic of the climate is hot-dry summer and cold winter. The rainfall ware not received during crop seasons. The mean extreme and lowest temperatures documented during the crop period ranged between 16.4°C to 30.6°C and 7.6ºC to 18.70ºC, respectively. The RH (%) documented during the crop growth ranged from 80.4 to 96.6% at 7 AM, whereas at 2 PM, it ranged between 51.9-84.3%. The soil in the experimental plot was calcareous-alluvium and slightly alkaline with pH 8.31, EC 0.34 dSm^{-1}, medium in organic carbon (0.48%), medium in available nitrogen (225 kg/ha), medium in phosphorus (17.8 kg/ha), medium in potassium (133.4 kg/ha) and low in zinc (0.5 ppm). The experiment was laid out in a Randomized Block Design with four replications. The treatments were consist of ten different application method and times of zinc *viz*., T1- Control, T2- Soil incorporation of ZnSO4 @ 12.5 kg ha^{-1} at the time of planting, T3- Soil incorporation of ZnSO4 @ 25 kg ha^{-1} at the time of planting, T4- Foliar application of ZnSO4 @ 2g $litre^{-1}$ after 25 days of planting, T5- Foliar application of ZnSO4 @ 2g $litre^{-1}$ at 25 and 50 days after planting, T6- T2 +Foliar application of ZnSO4 @ 2g $litre^{-1}$ after 25 days of planting, T7- T2 +Foliar application of ZnSO4 @ 2g $litre^{-1}$ at 25 and 50 days after planting, T8- Tuber treatment with ZnO for 12 hours, before planting, T9- Chelated Zn @ 4 g $litre^{-1}$ at 25 days after planting and T10- Chelated Zn @ 4 g $litre^{-1}$ at 25 and 50 days after planting. Potato planting was done with the variety *Kufri Khyati* in specified planting configurations per treatments in the winter of 2021-22. For planting, uniform-sized tubers weighing 30-40 g were selected. The tubers were treated with a 0.2 per cent 'Indofil' M-45 solution for 10 min to get rid of fungus and then planted after drying in the shade. Tuber planting was done with a row-to-row spacing of 60 cm and a plant-to-plant distance of 20 cm on the line directly close to the fertiliser line. Twenty tubers were planted in each row, with a four-meter length. Each experimental plot had eight rows of potatoes. Following that, earthing-up was done to cover the tubers to a height of 20 cm on the ridge. Fertiliser doses of 150: 90: 100 kg N: P: K ha^{-1} were recommended. The recommended dose of P and K, as well as half of the required dose of N, were provided as a basal application, while the rest half dose of N was given 40-45 days after planting, respectively. The initial irrigation was applied 20 days after planting. Aside from these three irrigations, additional irrigations were used as needed. The biometric observations on various days after planting, *viz*., 45, 60, and 75, were recorded, and the yield attributes were recorded at harvest time. The data for each character was analysed using the "analysis of variance" approach. As Cochran and Cox (1959) indicated, overall differences were evaluated using the "F" test of significance at a 5% significance level. Critical differences at a 5% probability level were computed for comparing treatments.

Result and Discussion

Response of zinc with different application methods on growth of potato (*Solanum tuberosum* L.)

Plant height

All the biofortification techniques significantly influenced the growth attributes of potato *viz*., plant height, number of shoots per plant, number of leaves per plant, dry matter production, and tuber bulking rate. Among ten different methods and time of application of zinc, the treatment T10 - (Chelated Zn @ 4 g $litre^{-1}$ at 25 and 50 DAP) recorded maximum plant height (Table. 1) at 45 DAP (38.26 cm), 60 DAP (48.75 cm), 75 DAP (57.68 cm) and harvest (59.90 cm) as compared to other treatments which were statistically similar with treatments, T2 (Soil incorporation of ZnSO4 @ 12.5 kg ha^{-1} at the time of planting), T3 (Soil incorporation of ZnSO4 @ 25 kg ha^{-1} at the time of planting), T5 (Foliar application of ZnSO4 @ 2 g $litre^{-1}$ at 25 and 50 DAP, T7 (T2 + foliar application of ZnSO4 @ 2 g $litre^{-1}$ at 25 and 50 DAP) and T9 (Chelated Zn @ 4 g $litre^{-1}$ at 25 DAP). The rise in height might be due to the taking up of Zn in the plant; Zn produces the auxin and availability of Zn to the leaves in the plant in the apical portion, which enhances the plant height. This enhancement in height is because of the supply of plant nutrients in balanced proportion and the appropriate amount, which helped in producing more protoplasm and, at this moment, enhancing the rapid division of cell and elongation of cells, which exhibited in the form of improvement in the height of the plant. A similar plant height increment on the application of chelated Zn was observed by Kalaiselvan *et al*. (2021) [4].

Number of shoots per plant

The number of shoots per plant at harvest showed a substantial variation in potato's shoot number across various treatment groupings. The treatment T10 (chelated Zn @ 4 g $litre^{-1}$ at 25 and 50 DAP) recorded the maximum shoots number per plant at 45 DAP (3.15), 60 DAP (4.75), 75 DAP (5.25) and harvest (5.25) which was significantly superior with T1 (Control), having 2.11, 3.75, 4.05 and 4.05 shoots/plant at 45, 60, 75 DAP and harvest respectively (Table. 2). Similar observations were recorded by Kamboj *et al*. (2019) [5]. Due to Zn's metabolic involvement in protein synthesis, enzyme activation, and glucose metabolism, Zn fertilizer improves potato tubers' qualitative and quantitative performance.

Number of leaves per plant

The number of leaves increased significantly in treatments with Zn fertilizer over control, with the maximum number of leaves per plant (Table. 3) found under treatment T10 (Chelated Zn @ 4 g litre-1 at 25 and 50 DAP) at 45, 60, 75 DAP and harvest, as the role of Zn is in auxin production which increases vegetative growth and development of the plant. Similar research findings were observed by Kaur *et al*. (2018) [6]; this could be because plants had a sufficient supply of Zn, which speeds up enzymatic activity and auxin metabolism.

Dry matter accumulation

The data on the progressive accumulation of dry matter (gm/plant) showed a substantial variation across various treatment groupings. The same trend of treatment T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) registered maximum dry matter accumulation (Table. 4) at various days of the planting of 45 DAP (27.80 g), 60 DAP (32.30 g), 75 DAP (43.62) and harvest (84.22). Whereas treatment T10 (Control) recorded the lowest dry matter accumulation in all the stages (Table. 4). The higher Zn nutrition during the early stages of plant growth facilitated earlier plant growth and enhanced dry matter production, maybe the cause of the improved dry matter yield. Due to larger leaves and taller plants, there was an increase in the accumulation of dry materials. This observation was like Bashir *et al*. (2021) [2], who observed that applying chelated Zn improved the dry matter content of the maize crop.

Tuber Bulking Rate (g day^{-1} plant^{-1})

Regarding the tuber's bulking rate increased significantly due to the application of Zn fertilization. Among the different application methods of zinc biofortification techniques, the maximum tuber's bulking rate was registered with treatment T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) at 45 to 60 DAP (4.20 g day^{-1} plant-1), 60 to 75 DAP (8.64 day^{-1} plant^{-1}) and 75 to harvest (3.54 day^{-1} plant^{-1}) had a significant effect compared to T10 (control) (Table. 5). Researchers' studies show Zn fertilization has a favourable impact on potato crop output and quality indices. Applying Zn to potato increased productivity, quality of plant development, number of tubers, average tuber weight, food material synthesis and its transfer to growing tubers, increasing tuber size. Similar findings were observed by Mahmud *et al*. (2021) [7] in potato crop.

Response of zinc with different application methods on yield of potato

Number of tubers per plant

The data concerning the number of tubers per plant revealed that various treatments substantially influenced the number of tubers per plant. The higher number of tubers per plant of 7.89, 11.89 and 12.40 at 60, 75 DAP and harvest, respectively, was noticed in treatment T10 (Chelated Zn @ 4 g litre-1 at 25 and 50 DAP). T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) also documented statistically similar with T3 (Soil incorporation of ZnSO4 @ 25 kg ha^{-1} at the time of planting) and T5 (Foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP) and least number of tubers/plant was noticed with treatment T1 (Control) (Table. 6). This finding was similar to work done by Mahmud *et al*. (2021) [7], as Zn improves vegetative growth, and increases photosynthesis of plant, which in turns help in better translocation of synthates to various parts, thus increasing overall growth and growth characters.

Total yield (t/ha)

The recorded data of yield revealed that Zn fertilizers had a significant effect on the yield of various treatments, where T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) had a maximum significant yield (25.17 t/ha), whereas T1 (Control) had minimum yield (20.88), whereas T3 (Soil incorporation of ZnSO4 @ 25 kg ha^{-1} at the time of planting), T5 (Foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP), T6 (T2 + foliar application of ZnSO4 @ 2 g litre^{-1} at 25 DAP), T7 (T2 + foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP, and T9 (Chelated Zn @ 4 g litre^{-1} at 25 DAP) were statistically at par with T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) (Table. 7). 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. Due to its role in forming RNA polymerase enzymes and carboxyl phosphate, this element increases the amount of glucose and starch in plant tissue, increasing yield. The result was similar to that of Namini *et al*. (2021) [9].

Haulm yield (t ha^{-1})

T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP) had a significantly produced maximum haulm yield of 11.41 t/ha (Table. 7) among all treatments. In contrast, T1 (Control) had a minimum yield of 9.55 (t/ha), whereas T2 (Soil incorporation of ZnSO4 @ 12.5 kg ha^{-1} at the time of planting), T3 (Soil incorporation of ZnSO4 @ 25 kg ha^{-1} at the time of planting), T5 (Foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP), T6 (T2 + foliar application of ZnSO4 @ 2 g litre^{-1} at 25 DAP), T7 (T2 + foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP, and T9 (Chelated Zn @ 4 g litre^{-1} at 25 DAP) were statistically at par with treatment T10 (Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP). 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*. (2021) [3].

Harvest Index (%)

The Harvest index was statistically non-significant. However maximum harvest index (69.67) was obtained from T6 (T2 + foliar application of ZnSO4 @ 2 g litre^{-1} at 25 DAP) and minimum (67.91) with T5 (Foliar application of ZnSO4 @ 2 g litre^{-1} at 25 and 50 DAP) (Table. 7). This might be due to the higher photosynthetic rate during the tuberization period and the partitioning of photosynthates to sink. This result was supported by Nag (2006) [8] and Patel (2013) [10].

Table 1: Plant height (cm) at 45, 60 75 and at harvest

S.no.	Treatment Details	45 DAP	60 DAP	75 DAP	Harvest
T_1	Control (No Zn)	33.37	43.25	50.44	52.41
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	35.38	44.12	56.25	56.26
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	37.68	46.54	53.55	54.84
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	34.54	44.25	51.59	52.77
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	38.11	45.75	55.24	57.47
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	34.50	43.88	51.75	53.38
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	35.87	44.75	53.5	54.5
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	34.38	43.82	51.87	53.52
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	36.38	45.97	55.5	58.39
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	38.26	48.75	57.68	59.9
	S.Em (±)	1.32	1.67	2.01	2.11
	LSD (*p*=0.05)	3.82	4.83	5.84	6.13

Table 2: Number of shoots per plant at 45, 60, 75 DAP and at harvest

S.no.	Treatment Details	45 DAP	60 DAP	75 DAP	Harvest
T_1	Control (No Zn)	2.11	3.75	4.05	4.05
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	2.31	4.40	4.55	4.55
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	2.99	4.55	4.90	4.90
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	2.28	3.95	4.15	4.15
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	2.94	4.75	4.95	4.95
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	2.73	4.05	4.55	4.55
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	3.00	4.95	5.00	5.00
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	2.37	4.10	4.40	4.40
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	3.06	4.57	5.10	5.10
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	3.15	4.75	5.25	5.25
	S.Em (±)	0.09	0.15	0.17	0.17
	LSD (*p*=0.05)	0.27	0.45	0.50	0.50

Table 3: Number of leaves per plant at 45, 60, 75 DAP and at harvest

S. No.	Treatment Details	45 DAP	60 DAP	75 DAP	Harvest
T_1	Control (No Zn)	35.00	44.14	49.62	31.25
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	37.00	45.50	50.16	33.25
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	39.54	50.12	55.72	35.79
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	35.63	45.57	52.46	35.87
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	39.13	49.57	55.47	35.56
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	36.50	48.25	53.81	36.38
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	37.38	48.63	54.98	37.65
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	36.13	44.68	50.11	31.88
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	38.44	49.13	55.33	35.38
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	41.25	50.75	55.86	38.55
	S.Em (±)	1.36	1.80	1.91	1.17
	LSD (*p*=0.05)	3.95	5.22	5.55	3.40

Table 4: Dry matter accumulation (g per plant) at distinct growth stages

S. No.	Treatment Details	45 DAP	60 DAP	75 DAP	Harvest
T_1	Control (No Zn)	19.05	23.55	37.85	71.41
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	24.41	28.91	40.67	73.52
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	27.20	31.76	42.38	80.05
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	21.08	25.58	39.58	72.09
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	27.09	31.59	41.87	80.44
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	23.74	28.24	40.44	76.59
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	24.87	29.37	40.89	79.29
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	23.20	27.70	39.83	75.89
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	25.79	30.29	41.09	79.28
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	27.80	32.30	43.62	84.22
	S.Em (±)	0.94	1.03	1.46	2.76
	LSD (*p*=0.05)	2.74	3.00	4.23	8.01

Table 5: Tuber Bulking Rate at distinct growth stages (g day^{-1} plant^{-1})

S. No.	Treatment Details	45-60 DAP	60-75 DAP	75 DAP- Harvest
T_1	Control (No Zn)	3.20	5.21	2.10
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	3.80	6.28	2.68
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	4.20	8.53	3.22
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	3.55	5.40	2.27
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	4.10	8.05	3.05
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	3.75	6.13	2.42
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	3.98	6.47	2.84
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	3.63	5.62	2.40
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	4.00	6.73	2.98
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	4.20	8.64	3.54
S.Em (±)		0.14	0.24	2.09
LSD (*p*=0.05)		0.39	0.69	6.06

Table 6: Number of tubers per plant at distinct growth stages

S. No.	Treatment Details	60 DAP	75 DAP	Harvest
T_1	Control (No Zn)	5.21	8.71	9.22
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	6.28	9.78	10.29
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	7.34	11.39	11.90
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	5.28	8.78	9.29
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	7.12	10.84	11.35
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	6.01	9.51	10.02
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	6.55	10.14	10.65
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	5.73	9.23	9.74
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	6.79	10.29	10.80
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	7.89	11.89	12.40
S.Em (±)		0.23	0.36	0.35
LSD (*p*=0.05)		0.66	1.04	1.03

Table 7: Yield (t/ha) and Harvest Index (%)

S. no.	Treatment Details	Total Yield (t/ha)	Haulm Yield	H. I
T_1	Control (No Zn)	20.88	9.55	68.61
T_2	Soil incorporation of $ZnSO_4$ @ 12.5 kg ha-1 at the time of planting	22.13	10.41	68.01
T_3	Soil incorporation of $ZnSO_4$ @ 25 kg ha-1 at the time of planting	24.66	10.89	69.36
T_4	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	21.80	9.79	69.01
T_5	Foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	23.42	11.07	67.91
T_6	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 DAP	24.17	10.52	69.67
T_7	T_2 + foliar application of $ZnSO_4$ @ 2 g liter^{-1} at 25 and 50 DAP	24.74	10.95	69.32
T_8	Tuber treatment with ZnO (4%) for 12 hours, before planting	21.20	9.68	68.41
T_9	Chelated Zn @ 4 g liter^{-1} at 25 DAP	23.39	10.74	68.54
T_{10}	Chelated Zn @ 4 g liter^{-1} at 25 and 50 DAP	25.17	11.41	68.81
S.Em (±)		0.79	0.35	2.44
LSD (*p*=0.05)		2.30	1.01	NS

Conclusion

The study proved that the biofortified method of Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP on potato produced a higher yield and enhanced the growth and development of the crop. Adaptation of Chelated Zn @ 4 g litre^{-1} at 25 and 50 DAP biofortification method might be one of the better options for the farmers' increasing potato yield and income. Also, it will help avoid zinc deficiency in the Bihar region.

References

1. Anonymous. Potato Nutrition - International Potato Centre, Lima, Peru; c2011.
2. Bashir S, Basit A, Abbas RN, Naeem S, Bashir S, Ahmed N, *et al*. Combined application of zinc-lysine chelates and zinc-solubilizing bacteria improves yield and grain biofortification of maize (*Zea mays* L.). Plos. one. 2021;16(7):e0254647.
3. Choudhary RS, Yadav SK. Studies on effect of zinc application on quality and yield of soybean (*Glycine max* L.) under typic haplustepts soil. Indian Journal of Pure and Applied Biosciences. 2021;9(1):188-193
4. Kalaiselvan G, Senthil K, Shanmugasundaram R, Yuvaraja A, Saravanan S, Prabhaharan J, *et al*. Amino acid chelated zinc on growth and yield of cumbu napier hybrid grass-CO (BN), 2021, 5.
5. Kamboj S, Mathpal B. Improving rice grain quality by foliar application of plant growth regulators under various mode of Zn application. Plant Arch. 2019;19(2):2181-2184.
6. Kaur A, Singh G. Zinc and Fe application in conjunction with nitrogen for agronomic biofortification of field crops–a review. Crop and Pasture Science; c2022.
7. Mahmud NU, Ferdous Z, Ullah H, Ahmed NU, Molla SH, Anwar M. Effect of zinc on grading, quality and yield of potato (*Solanum tuberosum*) in Bangladesh. International Journal of Agricultural Technology. 2021;17:1821-1832.
8. Nag GP, Sarnaik DA, Verma SK, Tamrakar SK.

Integrated nutrient management in potato for Chhattisgarh plains. M. Sc. (Ag) Thesis; c2006. p. 94-95.
9. Namini SKA, Malakouti MJ, Ghavidel A. The effect of Zinc chelates and Potassium sulfate topdressing on alleviating the Cadmium (Cd) and Nitrate (NO 3-) toxicity in potato tubers of Ardabil province, Iran. International Journal of Agricultural Science and Food Technology. 2021;7(1):034-042.
10. Patel VP, Patel PS, Patel NH. Heterosis for tuber yield and its components in potato; c2013.