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EFFECT OF ZINC ON GROWTH, TUBER BIO-FORTIFICATION AND PRODUCTIVITY OF POTATO (*SOLANUM TUBEROSUM* L.) IN INCEPTISOLS

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ABSTRACT

A field experiment was conducted to study the effect of zinc application on growth, tuber biofortification and productivity of potato (*Solanum tuberosum* L.) in inceptisols. The total treatment numbers were seven which were replicated thrice in randomized complete block design. It was observed that there was no significant impact of Zinc application on potato plant emergence, shoots or leaves per plant and final plant stand at harvest per net plot area while growth parameters like plant height, leaf area index, dry matter accumulation and tuber bulking rate were significantly affected by the treatments and maximum was recorded with T_7 [RDF of NPK + soil application of zinc @ 2.5 kg ha^{-1} at the time of planting + foliar application of zinc sulphate @ 2 g L^{-1} at 25 and 50 days after planting]. The highest total tuber yield (31.45 t ha^{-1}), nutrient (N, P, K & Zn) uptake from soil, Zn content in tubers (24.53 mg kg^{-1}) and B:C ratio (2.10) was also recorded in T_7 followed by T_5 [RDF of NPK + foliar application of Zinc sulphate @ 2 g L^{-1} at 25 and 50 days after planting]. T_7 recorded 22.27% and T_5 recorded 20.33% higher yield than T_1 [RDF of NPK]. T_7 recorded higher uptake of N, P, K and Zn by 24.26%, 24.64%, 28.63% and 72.95%, respectively over T_1. The treatment T_7 increased the Zn content in tubers by 84.43% as compared to T_1.

Key words : Bio fortification, Potato, Yield, Zinc application.

Introduction

Potato (*Solanum tuberosum* L.) as a member of the family Solanaceae is one of the most important food crops all over the world. Potato is heavy nutrient requiring crop. Even though the micronutrient elements are required in very small quantity, many of Indian soils may not supply them in sufficient quantity needed for healthy growth and optimum yield of potato and Zinc is the most deficient micronutrient in Indian soils (52%). Zn plays an important role in biosynthesis of indole acetic acid (IAA) and in initiation of primordial for reproductive parts and partitioning of photosynthates towards them resulting in better flowering and fruiting (Himanshu *et al.*, 2008) and also acts as a metal component of many enzymes. Hence, application of Zinc becomes essential to increase the productivity of potato. Besides, Zn deficiency in edible plant parts results in micronutrient malnutrition leading to stunted growth and improper sexual development in humans and also affects multiple aspects of the human immune system. The use of Zn-fertilizers on plant kinds that have the ability to absorb Zn and accumulate Zn in their edible sections is an alternative method to raise the concentrations of Zn in crops (Graham *et al.*, 2007). This method, known as bio-fortification, promises to boost Zn concentrations in food and feed, while also boosting crop yields on unproductive soils.

200 g of fresh weight (FW) unpeeled potato tubers are thought to be able to provide 5.5 percent of the daily needs of adult male humans (*i.e.*, approx. 11 mg Zn; White *et al.*, 2009). The bio-availability of zinc in potato tubers is also potentially high due to the relatively high concentrations of organic compounds that stimulate zinc

absorption and low concentrations of compounds that inhibit zinc absorption (Burlingame *et al.*, 2009; Kärenlampi and White, 2009; White *et al.*, 2009). An easy method to enhance the quantity of bio-available zinc in diets heavy in potatoes would be to employ Zn-fertilizers to raise tuber Zn concentrations.

Materials and Methods

The experiment was carried out in 2021-22 and 2022-23 during the *Rabi* seasons at the District seed farm (C-Unit), B.C.K.V., Kalyani, West Bengal, India. The farm was located at 22°58'N latitude and 88°25'E longitude, at an elevation of 9 m above mean sea level (MSL) and in a medium land habitat. The experiment was set up on a field with uniform fertility and textural make-up that was well-connected to an electric pump through an earthen irrigation channel for regular and timely irrigation. During the experiment (November to March) temperature varied from 12ºC to 32ºC, relative humidity varied from 47.10% to 95.19% and the area received total 226.20 mm rainfall. After assessing the physico-chemical properties of the soil it can be said that the soil is of sandy loam type having pH 7.40, organic carbon 0.58%, 182.25 kg available N ha^{-1}, 16.85 kg available P ha^{-1}, 133.00 kg available K ha^{-1} and 1.49 mg available Zn per kg of soil (Table 1). The experiment was laid out in a randomized complete block design with 3 replications having 7 treatments *viz*. T_1 - RDF of NPK, T_2 - RDF of NPK + Soil application of Zinc @ 2.5 kg ha^{-1} at the time of planting, T_3 - RDF of NPK + Soil application of Zinc @ 5 kg ha^{-1} at the time of planting, T_4 - RDF of NPK + Foliar application of Zinc sulphate @ 2 g L^{-1} at 25 days after planting, T_5 - RDF of NPK + Foliar application of Zinc sulphate @ 2 g L^{-1} at 25 and 50 days after planting, T_6 - RDF of NPK +Soil application of Zinc @ 2.5 kg ha^{-1} at the time of planting + Foliar application of Zinc sulphate @ 2 g L^{-1} at 25 days after planting, T_7 - RDF of NPK + Soil application of Zinc @ 2.5 kg ha^{-1} at the time of planting +Foliar application of Zinc sulphate @ 2 g L^{-1} at 25 and 50 days after planting. The net plot size was 3 m × 3 m and the gross plot size was 4.2 m x 3.4 m (5 rows each with 15 plants). On November 26th, fungicide-treated chopped tubers of the potato variety "Kufri jyoti" weighing 30-40 g apiece were sowed at a depth of 3-4 cm and spacing of 60 cm × 20 cm. The appropriate N, P and K doses (200:150:150 kg ha^{-1}) were treated using urea, single superphosphate and potash muriate. As a base, half of N was mixed with all of P and K. The remainder of N was top dressed at 30 DAP before being earthed up. According to the therapies, zinc was administered by Zinc Bahar (21% zinc). To boost early crop growth, Sencor (metribuzin) was applied pre-emergence at 0.75 kg a.i. ha^{-1}, followed by one hand-weeding at 30 DAP. To protect the crop from late blight, two sprays of Dithane M-45 (mancozeb 80%WP) @ 0.2% were administered at 40 and 60 DAP. Dimethoate 30% EC (Rogor) @ 0.1% was also used to control aphids and other insects at 45 and 65 DAP. All two seasons crop was dehaulmed at 90 DAP in the last week of February, when it reached maturity.

Harvesting began 15 days after dehaulming, with crop lines opened using a plough. Potato tubers were

Table 1 : Physico-chemical properties of experimental soil.

Particulars	**Values**	**Method used**
Mechanical Composition		
1. Sand (%)	27.30	International Pipette Method (Piper, 1966)
2. Silt (%)	44.30	
3. Clay (%)	28.40	
4. Texture	Sandy Loam	
Chemical Composition		
	Rabi, 2021-2022	
1. Soil pH	7.40	Beckman's pH meter method in 1:2.5 soil: water sample (Jackson, 1967)
2. Organic Carbon (%)	0.58	Walkley and Black method (Jackson, 1967)
3. Available N (kg.ha^{-1})	182.25	Modified Kjeldal Method (Jackson, 1967)
4. Available P (kg.ha^{-1})	16.85	Olsen's Method (Jackson, 1967)
5. Available K (kg.ha^{-1})	133.00	Flame Photometer Method (Jackson, 1967)
6. Available Zn (mg.kg^{-1})	1.49	0.005 M DTPA solution adjusted to pH 7.3 (Soil: extractant::1:2) (Lindsay and Norvell, 1978).

hand excavated from each allotment. At harvest, each net plot area's tuber yield (t ha^{-1}) and total tuber yield (t ha^{-1}) were reported. The economic parameters (cost of cultivation, gross returns, and net returns) were calculated using market input and output prices. MSTAT-C software was used to conduct data analysis and mean comparisons in the experimental design.

Results and Discussion

Effect of zinc application on growth attributes of potato

The experiment found that zinc treatment had no effect on plant emergence, final plant stands per net plot area at harvest, number of shoots per plant, or number of leaves per plant, however it had a significant influence on plant height at 60 DAP (Table 2). At 60 DAP, plant height varied from 59.33 cm to 65 cm.

T_7 had the greatest plant height, which might be attributed to the influence of zinc on cell division and indole acetic acid activity. Dhakal *et al*. (2019) reported comparable findings. It was obvious that zinc spraying had a considerable impact on potato total dry matter accumulation at various phases of crop growth. T_7 had the largest total dry matter accumulation at 50, 65, and 80 DAP. Trehan and Sharma (2003), Mousavi *et al*. (2007), Kumar *et al*. (2008), and Taheri *et al*. (2012) all found an increase in potato dry matter accumulation as a result of zinc treatment. It was also clear that zinc administration had a considerable impact on potato tuber bulking rate. T_7 had the highest tuber bulking rate at 50-65 DAP and 65-80 DAP.

Effect of zinc application on tuber number and tuber yield of potato

Zinc treatment clearly impacted grade-specific tuber number and overall tuber number (Table 5). The treatment T_1 had the largest total number of 0 to 25 g grade tubers, followed by T_2, which might be attributed to zinc deficit, as zinc shortage increases the quantity of small sized potato tubers. T_5 had the largest amount of 25-75 g grade tubers, followed by T_7, which might be related to zinc treatment increasing the quantity of medium and big sized

Table 2 : Plant emergence and growth attributes of potato as influenced by Zinc application (pooled data of two years).

Treatment	Emergence (%)	Final plant stands at harvest/net plot	Plant height at 60 DAP (cm)	No. of shoots/plant at 60 DAP	No. of leaves/plant at 60 DAP
T_1	97.83	74.33	59.33	3.50	41.20
T_2	97.80	74.67	61.67	3.78	44.13
T_3	98.33	75.00	62.33	3.81	45.47
T_4	98.33	74.67	62.00	3.78	43.10
T_5	97.13	74.67	63.33	3.86	45.33
T_6	97.30	74.67	64.67	3.89	48.67
T_7	97.63	75.00	65.00	3.86	47.87
SEm±	1.85	0.29	0.72	0.14	2.07
CD (P=0.05)	NS	NS	2.16	NS	NS

Table 3 : Total dry matter accumulation of potato as influenced by the application of Zinc (pooled data of two years).

Treatment	Dry Matter accumulation (g m^{-2})		
	50 DAP	65 DAP	80 DAP
T_1	553.86	865.50	1011.48
T_2	567.28	879.60	1028.70
T_3	620.40	940.50	1110.70
T_4	570.30	878.50	1027.60
T_5	571.40	954.25	1129.80
T_6	622.60	943.70	1116.75
T_7	623.25	968.25	1136.30
SEm±	6.08	9.46	5.54
CD (P=0.05)	18.26	28.40	16.62

Table 4 : Tuber bulking rate of potato as influenced by Zinc application (pooled data of two years).

Treatments	Tuber bulking rate (TBR) (g m^{-2} day^{-1})	
	50-65 DAP	65-80 DAP
T_1	16.89	8.61
T_2	17.82	8.93
T_3	19.03	9.25
T_4	17.65	8.73
T_5	20.13	9.52
T_6	19.42	9.36
T_7	20.73	9.78
SEm±	0.45	0.13
CD (P=0.05)	1.35	0.40

Table 5 : Grade-wise and total tuber number (000'/ha) of potato as influenced by Zinc application (pooled data of two years).

Treatment	Grade-wise and total tuber number (000'/ha)			
	0-25g	25-75g	>75g	Total
T_1	106.69	113.91	132.80	353.40
T_2	104.46	116.13	114.47	335.07
T_3	83.90	134.47	122.25	340.62
T_4	96.69	117.80	142.25	356.74
T_5	75.01	154.48	133.92	363.41
T_6	96.13	137.81	101.69	335.62
T_7	75.01	153.37	103.91	332.29
SEm ±	2.20	2,23	11.26	2.98
CD (P=0.05)	6.62	6.70	NS	8.95

Table 6 : Grade-wise and total tuber yield (t ha^{-1}) of potato as influenced by Zinc application (pooled data of two years).

Treatment	Grade wise and total tuber yield (t/ha)			
	0-25g	25-75g	>75g	Total
T_1	2.60	6.70	16.42	25.72
T_2	2.45	6.28	18.06	26.78
T_3	1.83	8.50	19.22	29.56
T_4	2.11	5.83	18.78	26.73
T_5	1.56	8.67	20.72	30.95
T_6	2.61	7.67	19.51	29.79
T_7	1.28	9.39	20.78	31.45
SEm ±	0.13	0.14	0.34	0.49
CD (P=0.05)	0.40	0.42	1.02	1.46

tubers. T_4 had the most total number of tubers weighing more than 75 g, whereas T_6 had the lowest. T_5 had the most total tubers, followed by T_4. T_7 had the lowest overall number of tubers. Increased tuber number per plant with zinc treatment was also found by Sahota (1985), Puzina (2004), Sanderson & Gupta (1989), Taya *et al*. (1994) and Ahmed *et al*. (2011).

Zinc spraying had a substantial impact on grade wise potato yield and overall tuber yield (Table 6). T_6 generated the most tubers weighing 0-25 g, followed by T_1 and T_2. Treatment T_7 had the highest yield of 25-75 g grade tubers. The yield of more than 75 g tubers varied substantially from 16.42 to 20.78 t ha^{-1} due to the use of different treatments. The treatment T_7 produced the maximum yield of more than 75 g grade tubers (20.78 t ha^{-1}) followed by T_5. Mousavi *et al*. (2007) and Li *et al*. (2010) similarly showed increase in yield of more than 75 g grade tubers.

The overall tuber yield varied substantially between treatments, ranging from 25.72 to 31.45 t ha^{-1}. The

Table 7 : Total dry weight yield of potato tubers and haulm as influenced by Zinc application (pooled data of two years).

Treatments	Total dry weight yield of tubers (t ha^{-1})	Total dry weight yield of haulms (t ha^{-1})
T_1	4.24	3.21
T_2	4.41	3.36
T_3	4.86	3.73
T_4	4.40	3.35
T_5	5.10	3.89
T_6	4.90	3.76
T_7	5.18	3.92
SEm ±	0.10	0.07
CD (P=0.05)	0.26	0.21

treatment T_7 had the highest total tuber yield (31.45 t ha^{-1}) followed by T_5, which could be due to the fact that Zn application helped in increasing the average weight of individual tubers, thereby increasing tuber number in the medium and large grades and thus tuber yield due to increased translocation of starch from source to sink. Grewal *et al*. (1980), Amin *et al*. (1983), Uppal and Singh (1989), Sharma and Grewal (1990), Joshi & Raghab (2007), Mondal *et al*. (2007), Jam *et al*. (2015) and Parmar *et al*. (2016) all showed increases in potato production owing to zinc treatment.

The application of Zinc had a considerable impact on the total dry weight yield of tubers of the potato variety Kufri Jyoti (Table 7). The total dry weight yield of tubers varied substantially from 4.24 to 5.18 t ha^{-1} due to the use of different treatments. T_7 had the highest total dry weight yield of tubers (5.18 t ha^{-1}) followed by T_5. The treatment T_1 had the lowest total dry weight yield of tubers (4.24 t ha^{-1}). Ahmed *et al*. (2011) and Panitnok *et al*. (2013) both showed an increase in dry weight yield of potato tubers as a result of zinc treatment.

The total dry weight yield of haulms varied substantially from 3.21 to 3.92 t ha^{-1} due to the use of different treatments. The treatment T_7 produced the largest total dry weight yield of haulms (3.92 t ha^{-1}) followed by T_5, T_6 and T_3. The treatment T_1 had the lowest total dry weight yield of haulms. Treahn (1998), Puzina (2004) and Thakare *et al*. (2007) all found an increase in dry weight yield of potato haulms as a result of zinc treatment.

Effect of zinc application on nutrient uptake by potato

The application of zinc greatly enhanced the total nitrogen, phosphorous, potassium and zinc intake of

Table 8 : Nutrient uptake of potato and zinc content in potato tubers at harvest as influenced by zinc application (pooled data of two years).

Treatment	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Zn uptake (g ha^{-1})	Zinc content in tubers at harvest (mg kg^{-1})
T_1	107.65	29.42	150.19	172.84	13.30
T_2	112.66	31.00	157.10	200.46	15.03
T_3	124.98	34.44	180.64	269.29	17.47
T_4	112.45	30.84	157.01	211.03	19.13
T_5	131.34	36.04	187.26	289.47	23.70
T_6	125.82	34.81	175.80	243.34	20.30
T_7	133.77	36.67	193.20	298.93	24.53
SEm±	2.6	0.60	3.4	5.2	0.30
CD (P=0.05)	7.84	1.80	10.24	15.62	0.89

Table 9 : Cost of cultivation related to potato cultivation as influenced by Zinc application.

Treatments	Yield (t ha^{-1})	Seed (Rs ha^{-1})	Fertilizer (Rs ha^{-1})	Cultivation (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Sale price (Rs t^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1	25.72	48000	14614	70300	132914	231480	9000	98566	1.74
T_2	26.78	48000	15014	70300	133314	241020	9000	107706	1.81
T_3	29.56	48000	15414	70300	133714	266040	9000	132326	1.99
T_4	26.73	48000	14714	70940	133654	240570	9000	106916	1.80
T_5	30.95	48000	14871	71580	134451	278550	9000	144099	2.07
T_6	29.79	48000	15114	70940	134054	268110	9000	134056	2.00
T_7	31.45	48000	15271	71580	134851	283050	9000	148199	2.10

potatoes (Table 8). Greater yield resulted in greater N, P, K, and Zn absorption. Due to the application of different treatments, total N uptake varied significantly from 107.65 to 133.77 kg ha^{-1}, P uptake varied significantly from 29.42 to 36.67 kg ha^{-1}, K uptake varied significantly from 150.19 to 193.20 kg ha^{-1} and zinc uptake varied significantly from 172.84 to 298.93 g ha^{-1}. T_7 had the greatest total nitrogen (133.77 kg ha^{-1}), phosphorus (36.67 kg ha^{-1}), potassium (193.20 kg ha^{-1}) and zinc (298.93 g ha^{-1}) absorption, followed by T_5. The treatment T_1 had the lowest total nitrogen (107.65 kg ha^{-1}), phosphorus (29.42 kg ha^{-1}), potassium (150.19 kg ha^{-1}) and zinc (172.84 g ha^{-1}) absorption. Murmu *et al*. (2014), Ali *et al*. (2013) and Lenka & Das (2019) all observed an increase in N, P, K and Zn uptake as a result of zinc application.

Effect of zinc application on zinc content in potato tubers

Zinc treatment was found to have a considerable impact on the zinc concentration of potato tubers at harvest (Table 8). Zinc level in potato tubers at harvest ranged from 13.30 mg kg^{-1} to 24.53 mg kg^{-1} due to the use of various treatments. Treatment T_7 had the highest zinc concentration in potato tubers at harvest (24.53 mg kg^{-1}) followed by T_5. Treatment T_1 had the lowest zinc level in potato tubers at harvest (13.30 mg kg^{-1}). Mousavi *et al*. (2007), Ahmed *et al*. (2011), White *et al*. (2012), and Saha *et al*. (2014) all found an increase in zinc concentration in potato tubers as a result of zinc treatment.

Economics

The net return from potato production ranged from Rs. 98566 ha^{-1} to Rs. 148199 ha^{-1} (Table 9). The treatment T_7 produced the highest net return (Rs. 148199 ha^{-1}) and B: C ratio (2.10) and T_1 (RDF of NPK) produced the lowest net return (Rs. 98566 ha^{-1}) and B:C ratio (1.74).

Conclusion

As a result of the experiment, it can be concluded that application of recommended dose of N-P-K @ 200:150:150 kg ha^{-1} along with soil application of Zinc @ 2.5 kg ha^{-1} at planting and two foliar applications of Zinc sulphate @ 2 g L^{-1} at 25 and 50 days after planting is the most profitable for potato cultivation and it also recorded the highest tuber yield, Zinc content in tubers and nutrient uptake.

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