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Response of potato (*Solanum tuberosum* L.) to zinc application under lower *Gangetic* plains of West Bengal

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ABSTRACT

Field experiments were conducted during rabi seasons of 2015-16 and 2016-17 at the 'C-Block' Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to determine the response of potato to zinc application. The experiment was laid out in a Randomized Block Design with four replications having five treatments viz. T_1*- Recommended dose of fertilizer (RDF) of NPK,* T_2*- RDF of NPK + 1.5 kg Zn ha*$^{-1}$*,* T_3*- RDF of NPK + 3.0 kg Zn ha*$^{-1}$*,* T_4*- RDF of NPK + 4.5 kg Zn ha*$^{-1}$ *and* T_5*- RDF of NPK + 6.0 kg Zn ha*$^{-1}$*. Experimental results revealed that grade-wise tuber yield and total tuber yield were significantly influenced by zinc application. Tuber yield of potato cultivar 'Kufri Jyoti' was increased with increasing levels of zinc up to 6 kg ha*$^{-1}$*. The tuber yield (30.37 t ha*$^{-1}$*) and highest net return (` 81894 ha*$^{-1}$*) was obtained with RDF of NPK + 6.0 kg Zn ha*$^{-1}$ *as basal application which increased the total tuber yield by 20.32% over the control. Application of zinc significantly reduced the percentage occurrence of late blight and leaf spot disease in potato. Availability of NPK and Zn in post-harvest soil of potato was significantly influenced by application of zinc over RDF. The highest zinc availability (2.34 mg kg*$^{-1}$*) was observed in the treatment* T_5 *which was found statistically at par with the treatment* T_4 *and* T_3*.*

Keywords **:** Disease reactions, economics, nutrient status, potato, yield, zinc

West Bengal is the second largest potato growing state in India with a production of 9.7 million tonnes from an area of 409.7 thousand hectares, while the productivity was 19.75 t ha^{-1} during 2016-17 (Anon., 2017). The state accounts for one-third of the country's total potato production. At present, one of the major problems in potato cultivation in this area is decreasing yield trend due to micronutrient deficiencies at various locations. Micronutrients have received a great deal of importance in crop production during the recent years, because of the reports of widespread occurrence of their deficiencies from different parts of the country. Significant response of potato to micronutrient fertilization has also been reported by different investigators across the country. The main reasons for the occurrence of micronutrient deficiency is the adoption of intensive cropping programme with high yielding varieties of crops with the increase in irrigation facilities. The gradual shift to use of high analysis chemical fertilizers from the traditional system of recycling of nutrients through the use of crop residues and manures is also another contributing factor to this problem. Hence, for sustaining the agricultural productivity inclusion of micronutrients in the fertilizer schedule is very essential in modern agriculture. Reports say that, to produce optimum yield, potato plants need the application of micronutrient fertilizers from outside. There is growing awareness that micronutrients may limit potato yield even though they are required in small amounts by plants. Among micronutrients Zn has occupied a unique position to increase the yield of potato (Trehan and Grewal, 1989). Availability of Zn to plant is hampered by its immobile nature and adverse soil conditions. Thus, Zn deficiency is observed even though high amount is available in soil. Root-shoot barrier, a major controller of zinc transport in plant is highly affected by changes in the anatomical structure of conducting tissue and adverse soil conditions like pH, clay content, calcium carbonate content, etc. Applied Zn not only increase the medium and large size tuber number per sq. m in potato, but also it increase the average weight of individual tubers thereby increase the total tuber yield of potato (Sharma *et al*.,1988). Zn application helps in the translocation of sugars namely sucrose, glucose and fructose from leaves to tubers for biosynthesis of starch. Zn application increase starch synthesis due to the increased activities of starch synthesising enzymes in tubers (Uppal and Singh, 1989).

Keeping the above facts in view, this experiment was initiated with the objective to determine the response potato to zinc application in alluvial soil (Entisols) under lower *Gangetic* plains of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted for two consecutive years at the 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal (India) situated at 22º58′ N latitude and 88º3′ E

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longitude with an altitude of 9.75m above mean sea (MSL) during *rabi* 2015-16 and 2016-17. The soil of the experimental field was sandy clay loam in texture (Table 1) and slightly alkaline in reaction (pH 7.2) having an organic carbon content of 0.56%, 183.25 kg available N ha^{-1}, 16.8 kg available P_2O_5 ha^{-1}, 132 kg available K_2O ha^{-1}, 1.48 mg available Zn ha^{-1}. The experiment was laid out in a Randomized Block Design with four replications having five treatments *viz.* T_1- RDF of NPK, T_2- RDF of NPK + 1.5kg Zn ha^{-1}, T_3- RDF of NPK + 3.0 kg Zn ha^{-1}, T_4- RDF of NPK + 4.5 kg Zn ha^{-1} and T_5- RDF of NPK + 6.0 kg Zn ha^{-1} with a plot size of 5 m X 3 m. The crop was planted on 25th of November, 2015-16 and 2016-17, respectively. Tubers weighing 30-40 g each were planted in the furrows with a depth of planting of 3-4 cm and spacing of 60 cm × 20 cm and finally covered with soil. The recommended dose of fertilizer was 200, 150, 150 kg of N, P_2O_5, K_2O ha^{-1}which were applied through urea, single super phosphate and muriate of potash, respectively. Half of nitrogen, full dose of phosphorus and potassium were applied as basal. Rest half of N was top dressed at 30 days after planting (DAP) followed by earthing up. Zinc was applied as basal as per treatments in the form of Zinc Bahar (21% Zn) of Total Agri Care Concern Pvt. Ltd. Pre-emergence application of Sencor (metribuzin) @ 0.75 kg *a.i.* ha^{-1} was done at 3 DAP followed by one hand-weeding at 20 DAP to promote early crop growth. As a prophylactic measure, two rounds of spray of Dithane M-45 (mancozeb 80%WP) @ 0.2% at 40 and 60 DAP were given to protect the crop from the late blight disease. Dimethoate 30% EC (Rogor) @ 0.1% was also sprayed at 45 and 65 DAP for controlling aphids and other insects. Dehaulming was done in the last week of February in all the two seasons crop when it attained maturity. Harvesting was done 15 days after dehaulming and the crop lines were opened with the help of plough. Potato tubers were dug out from each plot manually. Data on grade wise tuber yield (t ha^{-1}) and total tuber yield (t ha^{-1}) were recorded at harvest from each net plot area. The economic parameters (cost of cultivation, gross returns and net returns) were worked on the basis of prevailing market prices of inputs and outputs. Analysis of variance of the data in the experimental design and comparison of means at pd”0.05 were carried out, using MSTAT-C software.

RESULTS AND DISCUSSION

Effect on plant emergence and yield

Experimental results revealed that emergence of plant from the tuber sown potato was not significantly influenced by the application of zinc over RDF of NPK. It ranged from 98.30 to 99.58%. The grade wise tuber production of potato was significantly influenced by zinc application over RDF of NPK (Table 2). Yield of potato tuber increased with increasing levels of zinc up to 6 kg ha^{-1}. The potato cv. Kufri Jyoti produced maximum tuber yield (30.37 t ha^{-1}) and marketable tuber (50-75g and > 75 g) yield in the treatment T_5 (RDF of NPK+ 6.0 kg Zn ha^{-1} as soil application) which might be due to the fact that Zn helped in increasing the average weight of individual tubers thereby increased the tuber number in the medium and large grades and as such the tuber yield due to increased translocation of starch from source to sink. Similar findings were also reported by Sharma *et al*. (1988), Uppal and Singh (1989), Das and Jena (1973). The lowest total tuber yield (25.24 t ha^{-1}) was recorded in control plot i.e. RDF of NPK only. It was observed that soil application of Zinc @ 6 kg ha^{-1} as basal over RDF of NPK increased the total tuber yield by 20.32% over the control (T_1).

Effect on tuber numbers and dry weight yield

Experimental results revealed that number of tuber production varied significantly from 283056 to 342778 per ha due to application of different treatments (Table 3). The highest number of tubers (342778 ha^{-1}) was recorded in the treatment T_5 (RDF of NPK+ 6.0 kg Zn ha^{-1} as soil application). Grade wise tuber numbers were also significantly influenced by the application of zinc over RDF. Application of zinc significantly increased the medium and large sized tuber numbers. Similar findings were also reported by Sharma *et al*. (1988) and Das and Jena (1973). The lowest number of tubers (283056 ha^{-1}) was recorded in the treatment T_1 (RDF of NPK). Soil application of zinc increased the total number of tubers by 21% over the control (T_1). The dry weights of tubers and haulms were significantly influenced by the application of zinc over RDF of NPK. The highest dry weight of tubers (5.84 t ha^{-1}) was recorded in the treatment T_5 (RDF of NPK+ 6.0 kg Zn ha^{-1} as soil application) and the least dry weight of tubers (4.70 t ha^{-1}) was recorded in the treatment T_1 (RDF of NPK).

Effect on post harvest soil nutrient status

The availability of nitrogen, phosphorus, potassium and zinc in soil after harvest of potato were significantly influenced by application of zinc over RDF of NPK (Table 4).

The nitrogen availability in soil after harvest of potato varied significantly from 161.2 to 178.5 kg ha^{-1}, phosphorus availability varied significantly from 16.85 to 17.75 kg ha^{-1} and potassium availability varied significantly from 121.0 to 129.3 kg ha^{-1} due to application of different levels of Zn over RDF of NPK. The highest nitrogen (178.5 kg ha^{-1}), phosphorus (17.75 kg ha^{-1}) and potassium (129.3 kg ha^{-1}) in soil after harvest

Table 1: Initial soil condition of experimental site

Soil parameters	Value	Methodology	Citation
Sand (%)	27.4	Hydrometer method	Bouyoucos (1962)
Silt (%)	44.4		
Clay (%)	28.2		
Textural class	Sandy clay loam	Soil textural triangle (USDA)	
pH	7.2		
EC (dS m^{-1})	0.25	(in 1:2.5:: Soil : Water)	Jackson (1967)
Organic carbon (%)	0.56	Wet oxidation method	Walkley and Black (1934)
Available N (kg ha^{-1})	183.25	Hot alkaline KMnO4 method	Subbiah and Asija (1956)
Available P (kg ha^{-1})	16.80	0.5 *M* NaHCO3 extract	Olsen *et al.* (1954)
Available K (kg ha^{-1})	132.0	Neutral *N* NH4OH extract	Hanway and Heidel (1952)
Available Zn (mg kg^{-1})	1.48	DTPA-TEA (pH 7.3) extraction	Lindsay and Norvell (1978)

Table 2: Emergence, grade-wise and total yield of potato tubers as affected by different zinc levels (Pooled)

Treatments	Emergence (%)	Grade-wise yield and total tuber yield (t ha^{-1})				Total
		0-25g	25-50g	50-75g	>75g	
T_1	99.30	0.63	3.14	5.17	16.31	25.24
T_2	98.93	0.88	2.81	5.42	17.33	26.43
T_3	99.58	1.25	4.08	6.67	15.47	27.47
T_4	98.30	1.36	2.89	6.20	18.42	28.86
T_5	99.25	1.04	2.89	5.53	20.92	30.37
SEm (±)	**0.60**	**0.10**	**0.24**	**0.27**	**0.33**	**0.48**
LSD (0.05)	**NS**	**0.28**	**0.73**	**0.80**	**0.96**	**1.28**

Table 3: Grade-wise tuber number and dry weight yield of potato tubers as affected by different zinc levels (Pooled)

Treatments	Grade-wise and total tuber number (no. ha^{-1})					Yield on dry weight basis (t ha^{-1})	
	0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
T_1	42500	56667	85000	98889	283056	4.70	3.14
T_2	47222	63611	88333	105000	304167	4.97	3.42
T_3	43889	54167	91945	111111	301111	5.22	3.67
T_4	48611	66111	98334	111111	324167	5.48	3.89
T_5	50278	71945	102778	117778	342778	5.84	4.11
SEm (±)	**2571**	**2706**	**1700**	**1402**	**4959**	**0.10**	**0.13**
LSD (0.05)	**NS**	**8117**	**5100**	**4204**	**14875**	**0.27**	**0.38**

Table 4: Post harvest soil nutrient status as affected by different zinc levels (Pooled data of 2 years)

Treatments	Soil nutrient availability (Post Harvest)			
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Zn (mg kg^{-1})
T_1	178.5	17.75	129.3	1.41
T_2	171.1	17.42	127.5	1.65
T_3	169.3	17.25	125.8	1.89
T_4	166.6	17.10	123.6	2.00
T_5	161.2	16.85	121.0	2.34
SEm (±)	2.9	0.23	2.4	0.17
LSD (0.05)	8.5	0.70	7.3	0.50

Table 5: Disease reactions as affected by different levels of zinc (Pooled)

Treatments	Late blight (%)	Leaf spot (%)	Viral disease (%)
T_1	31.65	21.48	0
T_2	12.45	18.67	0
T_3	12.88	14.25	0
T_4	10.07	12.27	0
T_5	7.96	7.53	0
SEm (±)	**0.78**	**0.62**	**-**
LSD (0.05)	**2.34**	**1.83**	**-**

Table 6: Economics and net returns of different treatments

Treatments	Yield	Cost of cultivation (₹ ha^{-1})			Cost (₹ ha^{-1})		Sale	Net
	(t ha^{-1})	Seed	Fertilizer	Cultivation	Inputs	Produce	price (₹ t^{-1})	returns* (₹ ha^{-1})
T1	25.24	32000	14614	50000	96614	151440	6000	54826
T2	26.43	32000	15542	50000	97542	158580	6000	61038
T3	27.47	32000	16466	50000	98466	164820	6000	66354
T4	28.86	32000	17399	50000	99399	173160	6000	73761
T5	30.37	32000	18326	50000	100326	182220	6000	81894

of potato was recorded in the treatment T_1 (RDF of NPK) might be due to lower uptake of N, P and K. The lowest nitrogen (161.2 kg ha^{-1}), phosphorus (16.85 kg ha^{-1}) and potassium (121.0 kg ha^{-1}) availability in soil after potato harvest was recorded in the treatment T_5 (RDF of NPK+ 6.0 kg Zn per ha as basal) might be due to higher uptake by the potato plant under balanced nutrition.

It was also observed that the zinc availability varied significantly from 1.41 to 2.34 mg kg^{-1} due to application of zinc at different levels over RDF of NPK. The highest zinc availability (2.34 mg kg^{-1}) was observed in the treatment T_5 (RDF of NPK+ 6.0 kg Zn ha^{-1} as soil application), which was found statistically at par with the treatment T_4 (RDF of NPK+ 4.5 kg Zn ha^{-1} as soil application) and T_3 (RDF of NPK+ 3.0 kg Zn ha^{-1} as soil application) which might be due to the fact that soil application of Zn helped in build up of Zn status in post-harvest soil (Mollah *et al.*, 2015). The lowest zinc availability (1.41 mg kg^{-1}) was recorded in the treatment T_1 (RDF of NPK), where no external source of Zn was applied in any form.

Results of the experiment revealed that, zinc application significantly reduced the late blight and leaf spot diseases in potato. The highest percentage occurrence of late blight (31.65%) and leaf spot (21.48%) was recorded where no zinc was applied (Table 5). The percentage occurrence of late blight and leaf spot gradually reduced with the increase in applied zinc levels. The lowest percentage occurrence of late blight (7.96%) and leaf spot (21.48%) were recorded with RDF of NPK + 6.0 kg Zn per ha as basal application. Thus, it was observed that applied zinc actively participated in reducing the incidence of different plant diseases of potato. Role of zinc in reducing late blight diseases in potato was also confirmed by Bhat *et al.* (2007). Studies have shown that certain micronutrients (especially Copper, Zinc and Boron) applied as foliar sprays or mixed with basic fertilizer are very effective in reducing late blight and in increasing tuber yield of potato (Frenkel *et al.*, 2010 and Montag *et al.*, 2006).

Economics

The results showed that potato cv. Kufri Jyoti fertilized with RDF of NPK + 6.0 kg Zn ha^{-1} as basal gave highest net return of rupees 81894 per ha (Table 6). Next best net return of rupees 73761/- per ha was recorded with RDF of NPK + 4.5 kg Zn ha^{-1} as basal. Thus, from economic point of view100% RDF of NPK along with 6.0 kg Zn ha^{-1} as basal for potato cv. Kufri Jyoti proved to be the best.

Thus, based on two years data it can be concluded that, application of 6.0 kg Zn ha^{-1} as basal over recommended dose of NPK was found to be the best treatment which recorded significantly higher marketable (medium and large sized) tuber yield , total tuber yield (30.37 t ha^{-1}) and highest net return of potato cultivar 'Kufri Jyoti' and it also significantly improved the post harvest zinc status of the soil.

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