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Nutrient use effeciency, yield attributes and comparative economics of potato crop (*Solanum tuberosum* L.) in response to zinc and boron nutrition in entisols of India

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Abstract
A field experiment was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to determine the effect of boron and zinc on growth and yield of potato under lower Gangetic plains of West Bengal. The experiment was laid out in a randomized block design with four replications having seven treatments viz. T1 (RDF of NPK 200:150:150 kg N: P2O5:K2O/ha), T2 (T1+2.0 kg B/ha as soil application), T3 (T1+ 4.5 kg Zn/ha as soil application), T4 (T1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application), T5 (T1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP), T6 (T1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP) and T7 (T1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP). The soil of the experimental field was sandy loam in texture and slightly alkaline in reaction (pH 7.35) having an organic carbon content of 0.57%, 183.26 Kg available N/ha, 16.80 kg available P/ha, 132.00 kg available K/ha. The available Zn and B content of initial soil were 1.48 mg/kg and 0.86 mg/kg respectively. The results revealed that the highest values of various nutrient use and uptake efficiency parameters were recorded with the foliar application of Zn and B. Also, the same trend was observed where the highest value of harvest index of 83.20% and returns per rupee invested above farmer‟s practice of 28.5% was observed in T7 (T1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP).

Keywords: Nutrient use efficiency, harvest index, returns per rupee of investment above farmer‟s practice

Introduction
Potato (*Solanum tuberosum L.*) as a member of the family Solanaceae is one of the most important food crops all over the world and is an important food crop grown in more than 150 countries in the world. Potato popularly known as 'The King of Vegetables' has emerged as fourth most important food crops in India after rice, wheat and maize. In Indian agriculture, potato being a cash crop, occupies a unique position due to its high nutritional value and protein quality as compared to that of cereals. Potatoes are heavy nutrient requiring crop because of their bulk yields within a short time having shallow root systems. In potato cultivation, some elements like Zn, B, S, and Mg can help in increasing the foliage coverage at initial growth stages and in the later stages, the translocation of assimilates is responsible for higher yield (Trehan and Grewal, 1981) [25]. It is a nourishing and wholesome food & plays a pivotal role in the farm economy.
Use of high analysis fertilizers and intensive cropping has led to deficiency of many secondary micronutrients in areas where crop intensity is high. 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. Zn deficiency results in severe yield losses and in acute cases plant death. Zn deficiency in edible plant parts results in micronutrient malnutrition leading to stunted growth and improper sexual development in

humans. Zn is inimitable element in several plant metabolic processes such as enzyme activation like RNA polymerases, superoxide dismutase, alcohol dehydrogenase, carbonic anhydrase, protein synthesis and metabolism of carbohydrate, lipid and nucleic acid (Cakmak 2000; Palmer and Guerinot 2009) [1, 19]. Also Zn ions are integral parts of Zn finger family of transcription factors controlling cell proliferation and differentiation (Palmer and Guerinot 2009) [19]. Besides these, Zn plays major role in chloroplast development and function, of which most important are the Zn-dependent activity of SPP peptidase and the repair process of photo system II by turning over photo-damaged D1 protein (Hansch and Mendel 2009) [11]. Thus cells need mechanisms for maintaining Zinc homeostasis when available supplies decrease (Eide, 2009) [7]. In plants, Zn deficiency reduces growth, tolerance to stress and chlorophyll synthesis (Kawachi *et al.* 2009; Lee *et al*. 2010) [13, 14].

Experiments have indicated that Zinc is most deficient micronutrient in potato grown soil followed by iron, copper, and manganese. Zinc is directly or indirectly required by several enzyme systems, auxins and in protein synthesis, seed production and rate of maturity. Zinc is believed to promote RNA synthesis, which in turn is needed for protein production. Zn is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot 2006) [9]. Zinc plays a key role in hormone biosynthesis, structural stability of organelles, cytochrome c synthesis, activation and proper function of a number of enzymes, protein synthesis, stability and integrity of the root cell plasma membrane.

Boron (B) is a micronutrient necessary for plant growth. It plays an important roles in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, good pollination and fruit set, seed development, synthesis of amino acids and proteins, nodule formation in legumes and regulation of carbohydrate metabolism. Boron deficiencies occur over a much wide range of soils and crops than do deficiencies are found most often in light soils, low organic matter contents and high soil pH levels (Mengel and Kirkby, 1978) [17]. Because of its role in fertilization and flowering processes of crops, B is being given special importance. If it is deficient, one of the first adverse effects is on flowering and fruiting and therefore, on the yield and quality of the crops. Adverse effects on the yield can occur even though no deficiency symptoms are evident on the foliage and it is known as hidden hunger. Boron deficiency is often an unsuspected enemy of crop production.

Boron is the micronutrient needed in the greatest quantity to ensure several key growth processes. It influences root and shoot growth, plant development and pollination. Alongside Potassium, Calcium and Magnesium, Boron is an important element present in the cell wall. Here, it acts as a cementing agent between pectins, providing cohesive strength for cell tissues. Therefore, Boron affects tuber storage quality characteristics. Boron also affects Calcium absorption, so supplies are important to ensure a balanced nutrition. Boron deficiency severely inhibits pollen germination and pollen tube growth as well as the viability of pollen grains (Dugger, 1973) [5]. Boron is unique among the essential mineral nutrients. It is the only element that is normally present in soil solution as non-ionized molecule over the pH range suitable for the plant growth.

Materials and methods

Experimental site

The field experiment was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 to study the effect of Boron and Zinc application on growth and productivity of potato under lower Gangetic plains of West Bengal at C-Unit Research Farm (Kalyani) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The farm is situated at 22º 58' N latitude and 88º 25'E longitudes with an elevation of 9 m. above mean sea level and the ecosystem was medium land. The experiment was laid out in the field which has homogeneous fertility and uniform textural make-up, and was well connected to an electric pump through an earthen irrigation channels for frequent and timely irrigation.

Edaphic conditions

Experimental field at C-Unit, BCKV, Kalyani lies in the Indo-Gangetic alluvial plains. The alluvial soils (Inceptisols) are deep, moderately fertile with adequate internal drainage. The composite samples from 0-30 cm. Depth were randomly collected from five places in the experimental field with the help of screw auger prior to know the initial fertility status of the experimental field. All the possible technical precautions as prescribed for standard soil sampling were also taken. Then soil samples were brought to the laboratory, air-dried and ground, thereafter sieved through 80 meshes. The soil samples thus obtained were subjected to various physical and chemical analyses, and the results obtained have been presented in Table 1.

Table 1: Physico-chemical properties of experimental soil

Particulars	Values	Methods Used
Mechanical Composition		
1. Sand (%)	27.40	International Pipette Method (Piper, 1966) [20]
2. Silt (%)	44.40	
3. Clay (%)	28.20	
4. Texture	Sandy Loam	

Chemical composition

1. Soil pH	7.35	Beckman's pH meter method in 1:2.5 soil:water sample (Jackson, 1967) [12]
2. Organic Carbon (%)	0.57	Walkley & Black method (Jackson, 1967) [12]
3. Total Nitrogen (kg ha^{-1})	183.26	Modified Kjeldal Method (Jackson, 1967) [12]
4. Available P (kg ha^{-1})	16.80	Olsen's Method (Jackson, 1967) [12]
5. Available K (kg ha^{-1})	132.00	Flame Photometer Method (Jackson, 1967) [12]
6. Available Zn (mg kg^{-1})	1.48	0.005 M DTPA solution adjusted to pH 7.3 (Soil:extractant::1:2) (Lindsay and Norvell,1978) [15].
7. Available B (mg kg^{-1})	0.86	Hot $CaCl_2$ extractant (Soil:extractant::1:2) and the amount of Boron extracted was determined by the Azomethine –H method of Wolf (1971) [28] with slight modification as suggested by Gupta (1979) [10].

Details of the treatments involved in the experiment

The details of the treatments concerned with the experiment are stated in Table 2.

Table 2: Treatment details

Treatments		Treatment Details
T_1	:	RDF of NPK (200:150:150 kg $N:P_2O_5:K_2O$/ha)
T_2	:	T_1+2.0 kg B/ha as soil application
T_3	:	T_1+ 4.5 kg Zn/ha as soil application
T_4	:	T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application
T_5	:	T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP
T_6	:	T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP
T_7	:	T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP

Calculation of nutrient uptake

The uptake of major nutrient elements like N,P,K and minor nutrient elements like Zn and B from each plot of potato was worked out on dry weight basis by multiplying the dry matter (DM) yield of the crops with corresponding content of nutrient element:

Uptake (kg/ha) = Concentration (%) X Yield (kg/ha)

Estimation of Zinc in plant sample

Plant samples digested with tri acid mixture of $HNO_3:H_2SO_4:HClO_4$ in the ratio 10:1:4 as described by Jansen (1978). After digestion it was cooled and filtered & then concentration of Zn was measured by an Atomic Adsorption Spectrophotometer by running standard.

Estimation of Boron in plant sample

Plant B was estimated by muffling of dried plant sample at 550°C. After cooling H_2SO_4 was added to it & later Ammonium acetate buffer (pH 5.5) and o.025M EDTA were added to it. After adding 0.9% Azomethine-H, solution the tube was vortexed and the reading was taken using Spectrophotometer at 420 nm reading.

Nutrient use efficiency

Partial factor productivity

Partial factor productivity (PFP) is a measure of efficiency of input use (Cassman *et al.*, 1998) [2]. It is calculated as a ratio of the economic yield of the crop to the amount of nutrient applied.

$$\text{PFP} = \frac{\text{Tuber yield of potato (kg/ha)}}{\text{Amount of nutrient applied (kg/ha)}}$$

Agronomic efficiency

Agronomic efficiency (AE) is expressed as the increase in the yield of the crop for every incremental application of a particular nutrient in comparison to that of the control (Novoa and Loomis, 1981) [18].

$$\text{AE} = \frac{\text{Tuber yield in treatment(kg/ha)} - \text{Tuber yield in control (kg/ha)}}{\text{Nutrient applied in treatment (kg/ha)} - \text{Nutrient applied in control (kg/ha)}}$$

Uptake efficiency

Uptake efficiency (UE) is the measure of the percentage of the total plant nutrient uptake in a particular treatment versus that of control to the amount of nutrient applied in the treatment (Cassman *et al.*, 1998) [2].

$$\text{UE} = \frac{\text{Nutrient upatke in treatment(kg/ha)} - \text{Nutrient upatke in control (kg/ha)}}{\text{Nutrient applied in treatment (kg/ha)}} \text{ X 100}$$

Biomass nutrient use efficiency

Biomass nutrient use efficiency (BNUE) is the measure of the percentage of total biomass yield in the treated plot versus that in control to the difference in nutrient uptake between that of treated and control plots (Cassman *et al.*, 1998) [2].

$$\text{BNUE} = \frac{\text{Biomass yield in treatment(kg/ha)} - \text{Biomass yield in control (kg/ha)}}{\text{Nutrient uptake in treatment (kg/ha)} - \text{Nutrient uptake in control (kg/ha)}} \text{ X 100}$$

Physiological nutrient use efficiency

Physiological nutrient use efficiency (PNUE) is the measure of the percentage of total tuber yield in the treated plot versus that in control to the difference in nutrient uptake between that of treated and control plots (Craswell and Godwin, 1984) [3].

$$PNUE = \frac{\text{Tuber yield in treatment(kg/ha)} - \text{Tuber yield in control (kg/ha)}}{\text{Nutrient uptake in treatment (kg/ha)} - \text{Nutrient uptake in control (kg/ha)}} \text{ X 100}$$

Recovery efficiency

Recovery efficiency (RE) is the percentage of the difference between nutrient uptake in the treated and control plots over the amount of nutrient applied (Craswell and Godwin, 1984) [3].

$$\text{RE} = \frac{\text{Nutrient uptake in treatment (kg/ha)} - \text{Nutrient uptake in control (kg/ha)}}{\text{Amount of nutrient applied (kg/ha)}} \text{ X 100}$$

Yield attributes

Total dry matter production

For recording dry matter accumulation, one plant from the penultimate row in each plot were uprooted carefully and then sun-dried. After sun drying, the plant sample was separated into leaf, stem and tubers, and collected in paper bags carefully. Then samples were put in electric oven at 70°C for drying to obtain a constant dry weight, and finally expressed in g/plant.

Tuber bulking rate
Tuber bulking rate is defined as the increase in fresh weight of tuber per unit area of land per unit change in time and calculated by the following formula:

$$\text{TBR } ((\text{g/m}^2)/\text{day}) = \frac{W2-W1}{t2-t1} \text{X GA}$$

Where, W_2 and W_1 are the final and initial fresh weights of tuber per unit area at times t_2 (final time in days) and t_1 (initial time in days), respectively and GA is the ground area (m^2).

Yield of tubers
The middle two rows of potatoes in each plot were harvested for yield. Fresh weight of tubers (both grade-wise and total) from each plot was taken and finally represented in t/ha.

Harvest index
It is the ratio of economic yield (here, tuber yield) to the amount of total biomass produced by the crop. It is an indicator of economic outcome of the farmer and partitioning of dry matter towards the economic parts.

$$\text{HI} = \frac{\text{Total Tuber Yield (kg/ha)}}{\text{Total Biomass Yield (kg/ha)}} \text{X 100}$$

Comparative economics
Gross Return
The gross return was worked out from the total output before deducting the cost of cultivation.

Net Return
Net return was computed from the total output after deducting the total variable costs which also included the wages of manual labour.

Returns per rupee of investment
Return per rupee of investment (RRI) was also was worked out by dividing the gross return by the total cost of cultivation.

Returns per rupee of investment above farmer's practice
The "returns per rupee of investment above farmer's practice" (RRIFP) is calculated as a percentage of the increment in returns per rupee of investment of a treatment with respect to that of the farmer's practice.

$$\text{RRIFP} = \frac{\text{RRI in treatment (rupees)} - \text{RRI in farmer's practice(rupees)}}{\text{RRI in farmer's practice (rupees)}} \text{X 100}$$

Results and discussion
Nutrient use efficiency
Partial factor productivity
It was clearly evident from Table 3. that the partial factor productivity was significantly influenced by application of Boron and Zinc.
The partial factor productivity indicates the efficiency with which the input applied can be reflected in the economic yield of the crop. It can be seen that the highest value of PFP for both Zn and B of 25.1 were recorded in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which indicates that foliar application of the nutrients show higher input use efficiency.

Agronomic efficiency
Agronomic efficiency gives the rate at increase of unit yield per unit of nutrient applied in comparison to that of the control plot. Trends similar to that of PFP can be noticed in AE where the highest AE of 5.73 for both Zn and B is also recorded in in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) (Table 4)
However, while comparing the AE of Zn with that of B, it can be clearly seen that the treatments with the application of B along with the recommended dose of fertilizers showed higher agronomic efficiency to that of application of Zn along with the recommended dose of fertilizers. This indicates that B shows better improvement of yield than Zn.

Uptake efficiency
Nutrient uptake is the percentage of the nutrient content present in the total dry matter of the crop and uptake efficiency gives the rate at which the applied nutrient is converted to the dry matter in a particular treatment compared to that of the control for every unit of nutrient applied in the treatment. Hence, from Table 5 it is indicated that Zn has better use efficiency than B. The highest UE among Zn and B is observed for Zn of 11.61% in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP).

Biomass nutrient use efficiency
Biomass nutrient use efficiency (BNUE) indicates the incremental biomass yield increase per incremental increase in the plant nutrient uptake. It is evident from Table 6 that both Zn and B show the highest value of BNUE of 3.18% and 12.14% respectively in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP), which again indicates the superiority of foliar application for better uptake and biomass yield over soil application of the micro- nutrients.

Physiological nutrient use efficiency
Physiological nutrient use efficiency (PNUE) gives the incremental economical (here, tuber) yield increase per incremental increase in the plant nutrient uptake. As it can be seen from Table 7 the PNUE follows the same trend as that of BNUE in terms of highest value. However, it is interesting to note that the values of PNUE for B is significantly higher than that of Zn overall. This may be an indication that B is helpful in increasing the tuber yield of potato by channeling the photosysnthates towards the tubers.

Recovery efficiency
Recovery efficiency (RE) is the incremental increase in the plant nutrient uptake due to the applied nutrient. It is seen that the RE for both Zn and B follows the same trend as that of BNUE and PNUE in terms of highest value (Table 8). However, here, Zn shows better recovery efficiency than B overall.

Table 3: Partial factor productivity (PFP) of Zn and B as influenced by various treatments

Treatments	PFP (Zn)	PFP (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	13.1
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	5.3	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	6.3	14.2
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	23
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	20.9	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	25.1	25.1

Table 4: Agronomic efficiency (AE) of Zn and B as influenced by various treatments

Treatments	AE (Zn)	AE (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	1.48
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	0.17	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	1.16	2.61
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	3.63
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	1.49	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	5.73	5.73

Table 5: Uptake efficiency (UE) of Zn and B as influenced by various treatments

Treatments	UE% (Zn)	UE% (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	1.03
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	1.35	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	2.27	1.47
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	2.19
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	6.58	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	11.61	3.27

Table 6: Biomass nutrient use efficiency (BNUE) of Zn and B as influenced by various treatments

Treatments	BNUE% (Zn)	BNUE% (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	8.59
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	0.41	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	3.11	10.82
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	10.95
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	0.86	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	3.18	12.14

Table 7: Physiological nutrient use efficiency (PNUE) of Zn and B as influenced by various treatments

Treatments	PNUE% (Zn)	PNUE% (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	14.39
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	1.23	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	5.11	17.78
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	16.54
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	2.27	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	4.93	18.82

Table 8: Recovery efficiency (RE) of Zn and B as influenced by various treatments

Treatments	RE% (Zn)	RE% (B)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	---	---
T_2 (T_1+2.0 kg B/ha as soil application)	---	1.03
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	1.35	---
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	2.27	1.47
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	---	2.19
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	6.58	---
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	11.61	3.04

Yield attributes

Total dry matter (DM) production

It was clearly evident from Table 9 that the total dry matter production of potato at various stages of crop growth was significantly influenced by application of Boron and Zinc.

It was revealed that up to 50 DAP, the total dry matter production varied significantly from 546.20 to 619.40 g/m^2 due to application of different treatments. The highest total dry matter production up to 50 DAP (619.40 g/m^2) was recorded in the treatment T_4 (RDF of NPK+2.0 kg B/ha and

4.5 kg Zn/ha as soil application) which was found statistically at par with the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP). The lowest total dry matter production up to 50 DAP (546.20 g/m^2) was recorded in the treatment T_1 (RDF of NPK).

However, at 65 DAP, the total dry matter production varied significantly from 845.23 to 965.65 g/m^2 due to application of different treatments. The highest total dry matter production at 65 DAP (968.93 g/m^2) was recorded in the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which was found statistically at par with the treatment T_4 (RDF of NPK+2.0 kg B/ha and 4.5 kg Zn/ha as soil application). The lowest total dry matter production up to 65 DAP (845.23 g/m^2) was recorded in the treatment T_1 (RDF of NPK).

It was observed that at 80 DAP, the total dry matter production varied significantly from 980.64 to 1121.80 g/m^2 due to application of different treatments. The highest total dry matter production at 80 DAP (1126.05 g/m^2) was recorded in the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which was found statistically at par with the treatment T_4 (RDF of NPK+2.0 kg B/ha and 4.5 kg Zn/ha as soil application) which might be due to higher uptake of nutrients, better source to sink relation and higher translocation of starch. The lowest total dry matter production at 80 DAP (980.64 g/m^2) was recorded in the treatment T_1 (RDF of NPK).

Tuber bulking rate (TBR)

It was clearly evident from Table 10 that the tuber bulking rate of potato was significantly influenced by application of Boron and Zinc.

It was observed that from 50 to 65 DAP, the tuber bulking rate varied significantly from 17.60 to 20.15 g m^{-2} day^{-1} due to application of different treatments. The highest tuber bulking rate from 50 to 65 DAP (20.22 g m^{-2} day^{-1}) was observed in the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which was found statistically at par with the treatments T_4 (RDF of NPK+2.0 kg B/ha and 4.5 kg Zn/ha as soil application) and T_5 (RDF of NPK+ 0.1% boric acid as foliar application in three times at 40, 50 and 60 DAP). The lowest tuber bulking rate from 50 to 65 DAP (17.62 g m^{-2} day^{-1}) was found in T_1 (RDF of NPK).

It was observed that from 65 to 80 DAP, the tuber bulking rate varied significantly from 8.64 to 9.48 g m^{-2} day^{-1} due to application of different treatments. The highest tuber bulking rate (9.48 g m^{-2} day^{-1}) from 65 to 80 DAP was observed in the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which was found statistically at par with the treatment T_4 (RDF of NPK+2.0 kg B/ha and 4.5 kg Zn/ha as soil application). The lowest tuber bulking rate from 65 to 80 DAP (8.67 g m^{-2} day^{-1}) was recorded in T_1 (RDF of NPK).

Harvest index

It was clearly evident from Table 11 that the total tuber yield of potato variety Kufri Jyoti was significantly influenced by application of Boron and Zinc over RDF.

It was observed that the harvest index varied significantly from 73.18 to 83.20% due to application of different treatments. The highest harvest index of 83.20% was recorded in the treatment T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) which was found statistically at par with the treatment T_4 (RDF of NPK+2.0 kg B/ha and 4.5 kg Zn/ha as soil application) which might be due to the fact that B and Zn helped in increasing the average weight of individual tubers thereby increasing the tuber number in the medium and large grades (Lenka and Das, 2019) [16] 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) [22], Uppal and Singh (1989) [26], Das and Jena (1973) [4], Rashid *et al*. (2007) [21], Singh *et al*. (2013) [23] and Singh *et al*. (2014) [24]. The lowest harvest index of 73.18% was recorded in the treatment T_1 (RDF of NPK).

Table 9: Total dry matter production (DM) of potato as influenced by Boron & Zinc application

Treatments	DM (g/m^2) at different DAP		
	50 DAP	65 DAP	80 DAP
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	546.20	845.23	980.64
T_2 (T_1+2.0 kg B/ha as soil application)	565.25	877.50	1027.90
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	554.20	858.23	998.54
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	619.40	938.50	1095.60
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	570.50	925.25	1083.30
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	551.85	864.50	1010.50
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	615.42	965.65	1121.80

Table 10: Tuber bulking rate (TBR) of potato as influenced by Boron & Zinc application

Treatments	Tuber bulking rate (TBR) (g m^{-2}day^{-1})	
	50-65 DAP	65-80 DAP
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	17.60	8.64
T_2 (T_1+2.0 kg B/ha as soil application)	18.80	9.00
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	17.78	8.74
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	19.36	9.20
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	19.01	9.12
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	17.98	8.90
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	20.15	9.48

Table 11: Harvest index (HI) of potato as influenced by Boron & Zinc application

Treatments	HI %
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	73.18
T_2 (T_1+2.0 kg B/ha as soil application)	78.14
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	74.95
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	81.45
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	79.65
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	77.16
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	83.20

Comparative economics

Returns per rupee of investment above farmer's practice

It is sometimes seen in many field experiments that a particular treatment doesn't show significant economic gain over the existing farmer's practice. However, implementing the treatment in larger scales can alleviate the existing problems in the farmer's field. In this situation, it is important to quantify by how much a treatment contributes to better economic gains. Hence, calculating the "Returns per rupee of investment above farmer's practice" (RRIFP) serves the purpose. This will not only point out the best treatment in terms of economic gains, but also tell us by how much is it better than the existing farmer's practice in percentage in terms of remuneration. The percentage of economic gain over the farmer's practice gives us an accurate guide by which it can be extrapolated according to the area, extent and volume of the production and helps us in finding the actual gain in the farmer's field by implementing the treatment. This can also be used to find out the profitability of various combinations of the treatment in a simple manner using the existing data before implementing it on a larger scale.

It can be observed from Table 12, that the highest RRIFP of 28.5% is recorded in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP) and the lowest RRIFP value of 0.7% is recorded in T_3 (RDF + 4.5 kg Zn/ha as soil application). This shows the extent to which a particular treatment is helpful in giving remunerative gains to the farmer per unit of input used in addition to the existing practice followed.

Table 12: Comparative economics of potato as influenced by Boron & Zinc application

Treatments	Gross Returns (Rs./ha)	Net Returns (Rs./ha)	RRI (Rs./ha)	RRIF P (%)
T_1 (RDF of NPK 200:150:150 kg $N:P_2O_5:K_2O$/ha)	139500	42886	1.44	---
T_2 (T_1+2.0 kg B/ha as soil application)	157200	58919	1.60	11.1
T_3 (T_1+ 4.5 kg Zn/ha as soil application)	144000	44601	1.45	0.7
T_4 (T_1+2.0 kg B/ha and 4.5 kg Zn/ha as soil application)	171760	70695	1.70	18.1
T_5 (T_1+ 0.1% boron (boric acid) as foliar application in three times at 40, 50 and 60 DAP)	166600	69269	1.71	18.7
T_6 (T_1+ 0.1% zinc (zinc sulphate) as foliar application in three times at 40, 50 and 60 DAP)	150240	52766	1.54	6.9
T_7 (T_1+ Foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP)	180720	83189	1.85	28.5

Conclusions

In modern agriculture, micronutrients are becoming deficient day-by-day due to intensive cultivation with high yielding varieties of crops & use of high analysis fertilizers. In India, potato being a cash crop, occupies a unique place due to its high nutritional value.

It can be observed that the highest value of PFP, AE, UE, BNUE, PNUE and RE for both Zn and B of were recorded in T_7 (RDF + foliar spray of 0.1% zinc (zinc sulphate) + 0.1% boron (boric acid) at 40, 50 and 60 DAP). The same trend was found in both harvest index and returns per rupee of investment above farmer's practice.

It was observed that the effect of Boron in increasing tuber yield of potato was found more pronounced than Zinc under this experimental situation. However, foliar application of B & Zn was found superior to all the treatments including soil application in the experiment in increasing all the yield attributes of potato, thereby giving better remunerative returns to the farmer.

Future scope of research

Till date numerous studies have been conducted on yield response of potato to macronutrients (N, P & K mainly). So, more research on other micronutrients like Mn, Fe, Cu etc. should be done. More detailed study on bio-chemical parameters of potato should be studied like TSS, total lipid content etc. The present study was carried out with one potato cultivar 'Kufri Jyoti'. The response of other potato cultivars to Zinc & Boron should be studied. More detailed study on foliar application of micronutrients should be done.

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