Effect of foliar application of boron, zinc and manganese on dry matter accumulation, total tuber yield and economics of potato (*Solanum tuberosum*) cv. Kufri Chipsona – 1 under Gwalior climatic conditions

ABSTRACT

The present experiment was carried out at All India Coordinated Research Project on Potato running in the Department of Horticulture, Rajmata Vijyaraje Scindia Krishi Vishwa Vidyalya, Gwalior (M.P.) during Rabi 2018-19. The purpose of the experiment was to determine how different foliar treatment concentrations of boron, zinc, and manganese affected the production characteristics and yield of the potato variety Kufri Chipsona-1 in Gwalior climate conditions. Eight foliar spray treatments of micronutrients were included in the experiment. Three replications of each of these treatments were arranged in a Randomised Block Design. The use of zinc, manganese, and boron had a substantial impact on potato economics and overall tuber output, according to the data. Treatment T8 (Boron + Zinc + Manganese) had the highest overall tuber yield (30.57 t/ha), dry matter of tuber (250 g/kg), net profit (Rs 193541/ha), and B:C ratio (1.7). It has been determined that using boron, zinc, and manganese would increase crop production and yield profit in potato cultivation under the Gwalior climate.

Keyword: Potato Kufri chipsona -1, Boron, Zinc, Manganese and yield.

1. INTRODUCTION

In India, the area and output of potatoes are 2151 thousand hectares and 48237 million metric tonnes, respectively. In the Madhya Pradesh region of Gird, these figures are 111.06 thousand hectares and 2425 million tonnes, respectively [1]. Among India's vegetable crops, it holds the top spot both in terms of area and production. It makes up 283 % of the world's total vegetable output [2].

Carbs, minerals, and fibre are all found in potatoes. It has a similar protein content like milk and eggs. Because potatoes are high in lysine, one of the most vital amino acids, they are referred to be protective foods. A portion of a person's daily calorie demands are met by potatoes, which also contain a number of vital minerals and vitamins, such

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Comment [A2]: the same for other references such as no. 1 and so on as potassium, phosphorus, manganese, magnesium, foliate, vitamin C, and vitamin B-6 [3]. The average potato has 74.7% to 75.0% water, 22.9% sugar and starch, 0.1% fat, 0.6% minerals, 0.6% vitamins, and one of the highest percentages of protein and carbohydrate (1.21-2.00%) [4]. When compared to other crops like cereals, potatoes provide more dry matter and yield per unit area; for this reason, potatoes are regarded as a crop that requires a lot of nutrients [5].

Because potatoes produce a large amount of crop in a short growing season, they are regarded as a crop that requires a lot of nutrients. Crop development and growth depend heavily on balanced nutrition [6], with 17 key nutrients needed for plant growth and reproduction. When it comes to nutrients, some are needed in relatively high quantities (known as macronutrients) and others in smaller amounts (known as micronutrients). Despite being used in lower amounts, micronutrients are just as significant as macronutrients. Lead and zinc are two of the most important for fruit growth and pollination. For potato production to be effective, micronutrient control is essential.

In the high pH soils, micronutrient shortages might happen. In sandy loam soils, micronutrients administered topically or in the soil may have additional advantages for potato development when watered. Choosing an efficient application technique may also improve a particular micronutrient's utilisation and efficiency. Micronutrients are needed for potato plants to reach their maximum yield [7]. In the early phases of potato production, some minor plant nutrients, such as zinc and boron, may aid in boosting foliage; later on, assimilate translocation accounts for increased yield [8,9].

The efficacy of using macronutrients is enhanced by the presence of micronutrients. Micronutrients are very important to the compost program's goal of increasing sustainable agricultural yields. The reserve soil minerals and soil fertility are not always adequate to meet the demands of crop establishment and growth. Potato nutritional disorders are caused by both acidity and alkalinity in the soil. For crops to flourish, acidic soils require calcium, magnesium, and phosphorus, whereas alkaline soils lack zinc, manganese, and boron. Due to its tendency to grow an enormous vegetative mass and a large number of tubers per unit area, potatoes are a plant with high nutritional needs. It is an excellent consumer of micro and elements, as well as nitrogen, phosphorus, potassium, magnesium, and calcium [7,10,11,12].

Zinc is essential for protein synthesis, enzyme activity, and glucose metabolism. The use of fertilisers containing this component improves the potato tuber's qualitative and quantitative performance. Potato quality and performance will suffer as a result of the zinc shortage. Basic plant life activities, including (1) nitrogen metabolism, nitrogen intake, and protein quality; and (2) photosynthesis, which includes chlorophyll synthesis and carbon anhydrate activity, are significantly impacted by zinc. Manganese foliar treatments boost crop output because they improve the efficiency of photosynthesis and the synthesis of carbohydrates like starch [7,13]. Manganese plays a key metabolic function in nitrate metabolism by activating enzymes involved in glucose metabolism and lowering enzyme activity. As a result, deficits in manganese lower photosynthesis, which lowers crop production and quality [14, 15]. Utilising zinc and magnesium jointly from source sulphate zinc and magnesium improved potato crop productivity and quality [7,16]. [17] It was discovered that applying zinc and magnesium foliarly increased the potato crop's yield and quality. Zinc is essential to plant metabolism. The majority of enzyme structures, including dehydrogenases, aldolases, and isomerases, are somewhat impacted by this element when it comes to the Krebs cycle's energy generation [7,13]. Zinc has a role in protein synthesis, hormone production, cytoplasm synthesis, enzyme activation, and other processes.

This highlights the significance of zinc in potato farming. Potato crops are very susceptible to zinc treatment, depending on the variety's length. While reducing tyrosine and total phenol concentration in tubers and increasing ascorbic acid content, zinc fertilisation has been observed to enhance processing quality [18].

In the production of seed and cell walls, boron actively participates in the creation of proteins. From root to shoot, boron aids in the transfer of nutrients and water [19]. The range of concentrations between a boron shortage and toxicity varied greatly across plant species, and the range for boron was less than that of any other nutrient. Overboron had a negative impact on plant development and calcium absorption [20].Additionally, Mn has a major role in the structure of the photosynthesis-related enzymes [21,13, 22]. When Zn and Mn are used in potato cultivation, the number of tubers and their mean weight increase, which leads to good yield and quality [7,17, 23]. The foliar administration of elements such as zinc, manganese, copper, and magnesium is preferable to their direct application in soil because it eliminates nutrient shortages quickly, facilitates simple utilisation, reduces toxicity during collection, and prevents soil-stabilization of these elements [22].

Because potato yield and quality are dependent on the application of micronutrients, the current study was conducted with the following goals in mind after taking the aforementioned facts into account: 1) To determine how foliar treatment of zinc, manganese, and boron affects overall tuber yield; 2) To determine the impact of applying boron, zinc, and manganese foliarly on the economic viability of potato cultivation in the Gwalior climate.

2 **MATERIAL AND METHODES**

2.1 Experimental Location and Climatic Conditions

The experiment was carried out in Rabi 2018–19 in the Department of Horticulture, College of Agriculture, Rajmata Vijyaraje Scindia Krishi Vishwa Vidyalya, Gwalior (M.P.). In the Gird belt (MLS), the nursery of the College of Agriculture, Gwalior is located at 26^{o}13 N latitude and 78^{o}14' E longitude, 211.5 m above sea level. Its maximum temperature in May and June surpasses 45°C due to its subtropical climate. December and January saw the lowest temperatures. The last week of December through the first week of February is predicted to see frost. Typically, the monsoon season begins in the second week of June and lasts until September.

2.2 Soil of the experimental field

The experimental field's soil had a homogeneous contour and a texture of sandy clay loam. Using a soil auger, soil samples were randomly taken up to a depth of 20 cm from each plot in order to assess the textural class and fertility condition of the experimental area prior to seeding. To produce the primary samples, a composite soil sample was taken from each replication, and its physio-chemical characteristics were studied. Table 1 displays the information on the different physiochemical parameters.

Table 1: Physiochemical properties of soil collected from the experimental field.

S. No.	Composition	Content	Category
A. Mechanical composition			
1	Sand (%)	58	-
2	Silt (%)	19	-
3	Clay (%)	23	-
4	Textural class	-	sandy clay loam
B. Chemical composition			
S. No.	**Analysis**	**Values**	**Category**
1	Soil pH	7.6	Slightly alkaline
2	Electrical conductivity (dS/m)	0.32	Normal
3	Organic carbon (%)	0.45	Low
4	Available Nitrogen (kg N /ha)	197	Low
5	Available phosphorus (kg P_2O_5/ha)	19	Medium
6	Available potash (kg K_2O/ha)	241	Low

Table 2: Treatment and treatment application details

S. No.	Treatment (Application of)	Dose per litre
T_1	Control	water spray
T_2	Boron	2g
T_3	Zinc	1g
T_4	Manganese	2g
T_5	Boron + Zinc	2g + 1g
T_6	Boron + Manganese	2g + 2g
T_7	Zinc + Manganese	1g + 2g
T_8	Boron + Zinc+ Manganese	2g + 1g + 2g

The insecticide and micronutrient solution was prepared in a small container by adding its desired quantity (Zinc @ 1g/litre of water, Boron @ 2g/litre of water, Manganese @ 2g/litre and Control i.e. water spray) followed by brisk stirring with a piece of stick and its combination of micronutrients as per treatments. To produce the spray solution, these concentrate solutions were further diluted with clear water. Micronutrient spraying with a Foot sprayer needs two people. One person controlled the Foot sprayer's pedal while the other held the sprayer's lance to spray the solution. The first and second sprays were applied 30 and 45 days following potato planting, respectively.

2.3 Crop rising technology

A tractor pulled mould board plough was used to plough the field twice. Cross harrowing was done next, followed by planking to level the plot. Each plot received the recommended dosages of nitrogen, phosphorus, and potassium according on the treatment. Nitrogen, Phosphorus, and Potassium were supplied by Urea, DAP, and Muriate of Potash (MOP). The complete treatment and prescribed dosage of potassium and phosphorus were administered as basal that at the time of planting, half dose of nitrogen was applied as basal and the balance was applied at the first earthing-up mention days after planting. For seeding, healthy tubers with regular sizes of 35-40 mm and weights of 45-50 g were chosen. To check for fungal infection, pre-planting seed treatment was performed with Mancozeb 0.2% solution for 10 minutes and dispersed in a cold and wet environment. Planting was done with healthy, consistent, medium-sized tubers. The tubers were maintained in furrows 60 20 cm apart and covered with dirt using a ridger. Planting is done in the morning to prevent hot soil covering throughout the day on the plains. Before planting, tubers were treated with carbendazim 50% WP and Mancozeb 75% WP. Imidacloprid @4m/15 litre water was used to control the aphid population and prevent viral disease infection in potatoes after sowing. Mancozeb @25gm/15 litre of water is sprayed after tuber planting to control late blight of potato. Pre-irrigation was used before planting potato tubers, and four irrigations were used to keep moisture at optimal levels.

2.4 Observation recording methodologies

2.4.1 Computation of Economics of treatments

Several economic indexes are available to assess agricultural production profitability. Because the price of farm products varies from year to year, season to season, and location to location, no one indicator is capable of providing a meaningful comparison of alternative treatments. Instead, a variety of indices are used combined to assess the economic feasibility of the system. The system's profitability changes as a result. The indices used to calculate the economics of various therapies under consideration.

2.4.2 Gross Monetary Returns (Rs/ ha)

The entire monetary worth of economic production and by products generated from crops cultivated with various treatments is determined using local market values.

2.4.3 Cost of Cultivation (Rs/ ha)

Cost of cultivation is the total expenditure incurred for raising crop including treatment cost. The cost included for this purpose consists of own or hired human labour, owned or hired bullock labour, value of seed, micronutrients, manures, fertilizers, pesticides and herbicides and irrigation charges.

2.4.4 Net Monetary Returns (Rs/ ha)

It is computed by subtracting cost of cultivation from gross returns. It is good indicator of suitability of a crop growing practices since this represents the actual income of the farmer. Monetary returns for different treatments were calculated with the help of prevailing market rates of produce and different inputs used in the experiments.

Net monetary returns (Rs/ha) = Gross return (Rs/ha) – Cost of cultivation (Rs/ha)

2.4.5 Benefit cost ratio

It is the ratio of gross returns to total cost of cultivation. It is expressed as returns per rupee invested. This index provides an estimate of the benefit a farmer derives for the expenditure he incurs in adopting a particular set of production package of practices. Any value above 2.0 is considered safe as the farmer gets Rs. 2 for every rupee invested.

Benefit cost ratio = Gross return (Rs/ha) / Cost of cultivation (Rs/ha)

2.6 Statistical analysis

Data recorded on various aspects were tabulated and subjected to statistical analysis by using the techniques of analysis of variance. Treatment significance was tested by 'F' test. If 'F' test express the significant difference between the treatment mean values were tested with critical difference (CD) at 5% level of significance was computed.

3 RESULTS AND DISCUSSION

3.1 Total yield of tubers / ha (t)

The total yield of tubers / ha as affected by different treatments in Table 3. Tubers yield/ha were recorded between T_1 (16.59 t/ha) and T_8 (30.57 t/ha). Data indicated that the total tubers yield was highest in T_8 (30.57 t/ha) followed by T_7 (29.88 t/ha). Next better treatment was T_6 (27.67 t/ha).

Tubers yield/ha were recorded between T_1 (16.59 t/ha) and T_8 (30.57 t/ha). Data indicated total tubers yield highest in T_8 (30.57 t/ha), followed by T_7 (29.88 t/ha) that are comparable with [6, 24, 26] whoshowedthat 'Spunta' cv. produced higherunmarketable tuber than 'Diamant'and 'Cara'. Spraying Zn plus Mncombination at the lowestfrequency (one time each twoweeks) significantly reduced theunmarketable tuber yield, whilethe control treatment (no Zn plusMn combination was supplied)significantly increased the yield ofunmarketable tubers. The highestunmarketable tuber yield wasproduced with 'Spunta' whensupplied with no Zn plus Mntreatment (7.34 and 9.90 ton/ha in2005/2006 and 2006/2007,respectively). On contrary, theleast unmarketable tuber yield wasproduced by 'Cara' when treatedwith Zn plus Mn foliarcombination twice/week (3.60 and4.76 t/ha in 2005/2006 and2006/2007, respectively). Theadjusted means of totalunmarketable tuber yield (usingthe final plant stand/plot asindependent variable). Theresults clarified that the differenceeither between potato cultivars orZn plus Mn foliar combinationwith respect to total unmarketabletubers ton/ha is ascribed to thegenetic differences between tested cultivars and the appliedmicronutrients. On the other hand, the tuberyield differed significantly amongthe Zn plus Mn foliar fertilizertreatments. The highest yield wasobserved when supplying Zn plusMn foliar combination one timeevery two weeks (18.32 and 17.69t/ha in 2005/2006 and2006/2007, respectively), while thecontrol treatment (no Zn plus Mnfoliar fertilizer was applied)produced the least yield (15.24 and13.30 t/ha in 2005/2006 and2006/2007, respectively).'Spunta' cv produced thehighest yield of marketable tuberwhen supplied with Zn plus Mnfoliar combination one time everytwo weeks, while 'Cara' cvrecorded the least yield ofmarketable tubers when no Zn plusMn foliar combination wassupplied. As well as [7, 25, 27] stated that potato is relatively sensitive to Zn deficiency.Therefore it has sown a good reaction to zinc application. They carried out an experiment nearTabriz. Iran in 1997 and statistical analysis indicated that ZnSO4 was most effective inimproving yield and quality of potato compared to other treatments. In this study they found thatthe application of 20kg Zn/ha as ZnSO4 was highly effective and increased yield andproduction of potato to 3.5 t/ha, whereas application of 30kg Zn/ha as ZnSO4 improved thequality of potato.

Table 3: Total yield of tubers/ plot (kg) and/ hectare (tone) as influenced foliar application of of micronutrients

S. No.	Treatments	Total yield of tubers/ha (t)
T_1	Control	16.59
T_2	Boron	23.19
T_3	Zinc	25.39
T_4	Manganese	25.46
T_5	Boron + Zinc	23.61
T_6	Boron + Manganese	27.67
T_7	Zinc + Manganese	29.88
T_8	Boron + Zinc+ Manganese	30.57
SEm±		0.52
C.D. at 5%		1.61

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3.5 Dry matter

Mean dry weight of tuber were recorded between T_1 (213 gkg^{-1}) and T_8 (250 gkg^{-1}). Data indicated Table 6 mean dry weight of tuber was highest in T_8 (250 gkg^{-1}/sample) followed by T_6 (246gkg^{-1}/sample). Next better treatment was T_7 (240gkg^{-1}/sample).

Mean dry weight of tuber g kg^{-1} were recorded between T_1 (213/sample) and T_8 (250/sample). Mean dry weight of tuber gkg-^{1} was highest in T_8 (250), and T_6 (246). Similar confirmation observed by [22] Zn utilization and Mn increased dry matter percentage in potato tubers and this increase statistically was significant. Application of Zn at 8 ppt increased percent of dry matterup to 5% in compare with control and also Zn at 4 ppt increased dry matterup to 4.7% in compare with control. Application of Zn along with Mn also increased percent of dry matter, because by utilization of them together at 8 and 4 ppt percent of dry matter 12.2% increased. Whatever, application of Mn at 8 ppt decreased percent of dry matter. As well as [5,7] showed that application of 1.1 kg B /ha from borax increasedpotato fresh haulm weight/hill, No. of tuber/hill, dry matter % of tubers and yield of tuber /ha.

Table 4: Mean dry matter of potato as influenced foliar application of of micronutrients

S. No.	Treatments	Dry matter (g kg-1)
T_1	Control	213
T_2	Boron	233
T_3	Zinc	230
T_4	Manganese	229
T_5	Boron + Zinc	230
T_6	Boron + Manganese	243
T_7	Zinc + Manganese	240
T_8	Boron + Zinc+ Manganese	250
SEm ±		3.13
C.D. at 5%		9.59

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Economics

The Table 5 showed that the maximum operational cost was incurred by T_8 (112169) followed by T_7 (108453) and T_6 (109078). The maximum gross returns was observed in treatment T_8 (305710) followed byT_7 (298765) andT_6 (276698).The net profit were recorded between T_1 (72498 Rs / ha) and T_8 (193541 Rs / ha). The Cost-Benefit ratio was highest (1: 1.8) in T_7 followed by T_8 (1: 1.7), T_6 (1: 1.5), T_3 (1:1.5) and it was lowest (1:0.8) in case of T_1 (Table 8).

Table 5: Production cost of potato cultivation (Per ha)

A. Operational cost (Rs) per ha								
Operation	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**
Field Preparation @2500 Rs/ha	2500	2500	2500	2500	2500	2500	2500	2500
Labour cost for foliar spray @ Rs 861/ ha spray at 30, 50,70 day after planting.	00	2583	2583	2583	2583	2583	2583	2583
Planting@2500Rs/ha	2500	2500	2500	2500	2500	2500	2500	2500
Pesticidespray@287 Rs/day/ labour	1722	1722	1722	1722	1722	1722	1722	1722
Weedicide spray@ 287 Rs/day/ labour	1722	1722	1722	1722	1722	1722	1722	1722
Harvesting marketing transporting and grading @ 500 Rs/ tone	8294	11597	12692	12731	11805	13834	14938	15285
Sub Total (a)	**16738**	**22624**	**23719**	**23758**	**22832**	**24861**	**25965**	**26312**
A. Input cost (Rs) per ha								
Cost of seed @ 2000 Rs/Quintal	60000	60000	60000	60000	60000	60000	60000	60000
Pesticide @1500 Rs/ha	1500	1500	1500	1500	1500	1500	1500	1500

Weedicide @1500 Rs/ha	1500	1500	1500	1500	1500	1500	1500	1500
Micro-nutrients								
Zinc, Boron and Manganese cost	00	3300	1350	3150	4650	6450	4500	7800
of irrigation @2000 Rs/ha	12000	12000	12000	12000	12000	12000	12000	12000
Gunny bag @ 5	1659	2319	2539	2546	2361	2767	2988	3057
Sub Total (b)	**76659**	**80619**	**78889**	**80696**	**82011**	**84217**	**82488**	**85857**
C. Total (a+b)	**93397**	**103243**	**102608**	**104454**	**104843**	**109078**	**108453**	**112169**
D. Gross Return (Rs) per hectare								
Tuber yield Tone/ha	16.59	23.19	25.39	25.46	23.61	27.67	29.88	30.57
value (Rs)1000	**165895**	**231944**	**253858**	**254630**	**236111**	**276698**	**298765**	**305710**
Total	**165895**	**231944**	**253858**	**254630**	**236111**	**276698**	**298765**	**305710**
E. (D - A+B) Net Return (Rs) per hectare								
Gross Return (D)	165895	231944	253858	254630	236111	276698	298765	305710
Total cost (a)+(b)	93397	103243	102608	104454	104843	109078	108453	112169
Net Profit	**72498**	**128701**	**151250**	**150176**	**131268**	**167620**	**190312**	**193541**

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Table 6: Net profit and C.B. Ratio

S. No.	**Treatments**	**Net profit (Rs/ha)**	**Cost (Rs/ha)**	**B:C Ratio**
T_1	Control	72498	93397	0.8
T_2	Boron	128701	103243	1.2
T_3	Zinc	151250	102608	1.5
T_4	Manganese	150176	104454	1.4
T_5	Boron + Zinc	131268	104843	1.3
T_6	Boron + Manganese	167620	109078	1.5
T_7	Zinc + Manganese	190312	108453	1.8
T_8	Boron + Zinc+ Manganese	193541	112169	1.7

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CONCLUSION

The current study was conducted in the Department of Horticulture, Rajmata Vijyaraje Scindia Krishi Vishwa Vidyalya, Gwalior (M.P.), as part of the All India Coordinated Research Project on Potato (Solanum tuberosum), which ran from Rabi 2018-19.The study's goal was to see how different foliar spray concentrations of zinc, manganese, and boron affected the production metrics and yield characteristics of potatoes (Cv. Kufri Chipsona 1) cultivated under favourable climatic circumstances. The findings revealed that the application of boron, zinc, and manganese had a substantial influence on overall tuber production and potato economics. Among the studied treatments, T8 had the greatest overall tuber production (30.57 t/ha) and the largest mean dry matter of tubers per plant (250 g/kg). The findings of the Boron + Zinc + Manganese treatment T8 revealed that T8 had the highest B:C ratio (1.7). Boron, zinc, and manganese have been demonstrated to increase crop yield and profit in potato production in the Gwalior climate.

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