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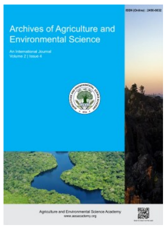

ORIGINAL RESEARCH ARTICLE

Responses of potato to different methods of zinc and boron application in midhills of Nepal

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ABSTRACT

Zinc (Zn) and boron (B) are important micronutrients for potato production and they play a critical role to achieve the potential yield. This research was conducted to evaluate the effects of the foliar and soil application of Zn, B, and agriculture lime in enhancing potato (cv. Khumal Bikash) yield and size of tuber. The experiment was conducted for two consecutive years (2022 and 2023) at the National Potato Research Program, Khumaltar, Nepal. Seven fertilizer treatments, namely T_1: recommended dose of NPK (RDF); T_2: RDF+ Zn+ B; T_3: RDF +B +Ag-lime; T_4: RDF +Zn +Ag-lime; T_5: RDF +Zn +B +Ag-Lime; T_6: RDF + (Z +B) foliar Spray; T_7: RDF + foliar Spray (2% urea +2% K) were arranged in a randomized complete block design. Foliar spray was applied twice, once at 40 DAP and again after 60 DAP. Ag-lime was applied before 15 DAP. Among seven treatments, T_6 (RDF +Zn +B foliar spray) showed a significant effect on yield (31.84 t/ha) and its variables including vigor, uniformity and ground cover of potato followed by T_5 (28.81 t/ha) and T_7 compared to the treatments without Zn and B. Foliar application of mixture of Zn and B (3 kg Zn/ha + 2 kg B/ha) significantly improved germination, vigor, sizes and number of tuber and total yield compared to a separate application of Zn or B. The treatment T6 (RDF + Zn + B foliar) demonstrated the highest micronutrient efficiency (1494 kg) highlighting the superior effectiveness of foliar application compared to other treatments. These findings suggest that micronutrients Zn and B is important to increase potato tuber yield and maximum benefits could be achieved with the foliar application at 2 splits.

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INTRODUCTION

Potato serves as a staple food in the high hills and mountains, major vegetable crop in the Terai and mid hills in Nepal and it plays a vital role in the food security in the country (Adhikari *et al*, 2023; Giri *et al*., 2023). In terms of area under potato cultivation, around 20% is in the high hills and mountains, 41.5% in the mid-hills and 38.5% in *Terai* (MoALD, 2016). Although it occupies the fifth position in area coverage, it is second in total production and the first in productivity among the food crops grown in Nepal (NPRP, 2022/23). In 2021/22, the total area under potato cultivation was 198,256 ha with the total production of 34,10,829 metric tons and an average productivity of 17.2 mt/ha. (NPRP, 2022/23). Potato yield is controlled by several factors including quality planting materials, irrigation, and fertilizer management practices. With optimum irrigation and quality planting materials, soil fertility and fertilizer management practice is considered one of the important yield limiting factors. It is reported that among micronutrients, zinc (Zn) and boron (B) are commonly deficient in potato production and they play a critical role in enhancing the yield of potato (Trehan & Grewal, 1989). With increasing cropping intensity and declining use of organic inputs in the soils, micronutrient deficiencies are commonly observed, particularly in the areas where cereals, oilseeds, pulses and vegetable crops are grown intensively (Kumar & Kumar, 2020). It is reported that application of deficient micronutrient could also increase uptake and use efficiency of macro nutrients (NPK). For example, foliar application of microelement solution (B, Cu, Mn, Zn and Mo) on potato leaves increased the uptake of N, P, K; chlorophyll content and photosynthesis in leaves, promoted the tuber expansion and increase potato yield (Kumar & Kumar, 2020; Singh & Singh, 2019). Application of micronutrients such and Zn and manganese (Mn) also affects protein and sugar content in potato tubers (Singh & Kathayat, 2018). Thus, micronutrients stimulate the uptake of other primary and secondary nutrients when applied in optimal concentration because of their interaction effects. The uptake of Zn is associated with uptake of phosphorous, iron associated with uptake of copper and magnesium, copper associated with uptake of Zn (Singh & Singh, 2019). The use of micronutrients such as Mo, B, Zn and Cu together with NPK is also improving potato yield and quality. It is reported that both Zn and B are the most deficient micronutrients in agricultural soils of Nepal (Andersen, 2007) and widely limit crop yields (Karki *et al.*, 2004; Shrestha *et al.*, 2020). Previous study reported that about 80 to 90% of soil samples analyzed from different parts of the country were deficient in B, 20 to 50% in Zn, and 10 to 15% in Mo (Andersen, 2007).

Micronutrient deficiency not only limit agricultural production, but also affect human nutrition (Andersen, 2007). In potato, micronutrients are applied either in soils or by foliar spray. Lenka & Das (2019) observed the highest total tuber yield (30.12 t/ha) with foliar application of 0.1% B + 0.1% Zn along with recommended dose of fertilizer (RDF) of NPK. A recent study recommends that foliar application of Zinc at 30 ppm to increase yield and quality of potato (Kumar & Kumar, 2020). Boron requirement is high after 45 days of crop emergence and remain high till crop maturity (Singh & Singh, 2019). Boron is slowly released from soil because it is tied up by soil organic matter and only becomes available with the decomposition (Shireen *et al.*, 2020). Lal *et al.* (2019) also reported that the foliar spray of $ZnSO_4$ and $CuSO_4$ (0.2%) micronutrients delayed the onset of late blight subsequently reduced disease severity with higher yield. Basal application to soil and/or foliar sprays of Zn, B and Mo have been recommended as the most suitable methods for correcting micronutrient deficiencies in many vegetable crops (Uikey *et al.*, 2018). Moreover, majority of the soils (>55%) in the country are acidic (Tripathi *et al.*, 2022). Soil pH pays a vital role in availability of plant nutrients. Thus, soil acidity may affect plant nutrient availability. However, there are very limited research studies on soil acidity and micronutrient availability. Therefore, this study was conducted to determine the effects of micronutrients Zn and B and their application methods and agriculture liming on potato tuber yield, tuber size in midland of Nepal.

Table 1. Treatment details of the experiment.

Treatment	Treatment details	Abbreviation
T_1	RDF(100:100:60 kg N: P_2O_5: K_2O/ha and FYM: 20t/ha)	RDF
T_2	RDF+Zinc(3 kg Zn/ha) + Boron (2 kg Boron/ ha)	RDF (+ZnB)
T_3	RDF+ Ag lime+ Boron	RDF (+Lime and B)
T_4	RDF+Zinc+Ag lime	RDF (+Lime and Zn)
T_5	RDF+ Zinc+ Boron+ Ag lime	RDF (+Lime and ZnB)
T_6	RDF+(Zn +B) foliar spray	RDF (+ZnB foliar)
T_7	RDF+(2% Urea + 2% MOP) foliar spray	RDF (+2% urea and 2% MoP foliar)

MATERIALS AND METHODS

Experimental site

The field experiment was conducted in the research field of National Potato Research Program, Khumaltar, Lalitpur for two consecutive years (2022-2023). It is located in central Nepal (longitude of 27^0 38' 54.6'' N and latitude of 85^0 19' 30.9'' E) at 1350 meters above sea level (NPRP, 2018) with sub-tropical climate. The soil properties of the farm before the experiment include soil pH 6.26, total nitrogen 0.11%, available P_2O_5:162.37 ppm, available K_2O 63.13 ppm, organic C 0.92%, available boron 2 ppm, available zinc 9.13 ppm and silty loam texture. Organic matter analyzed by Walkey Black method, total nitrogen by Kjeldahl method, potassium (K) by ammonium acetate extraction method, available phosphorus (P) by Bray P1 test, and soil pH by glass electrode pH meter.

Treatment details

Seven fertilizer treatments from the combination of recommended fertilizer dose (RDF) of NPK, micronutrients and agriculture lime (Table 1) were laid out in a randomized complete block design. Agriculture lime was applied 10 days prior to planting in the field based on the soil pH (0.425 kg per 7.2 m²). Foliar application of micronutrients (Zn, B) and urea and potassium (2% urea + 2% potassium) spray was done at 40 and 60 days after planting. Zn and B were applied as zinc sulphate and borax at the time of planting. Zinc sulphate was applied at the rate of 3kg Zn/ha and borax was applied at the rate of 2 kg B/ha. Recommended doses of fertilizers for potato were 100:100:60 kg N, P_2O_5 K_2O/ha and farm yard manure (FYM) 20 mt/ha and they were applied as recommended by Nepal Agricultural Research Council (NARC) The variety of potato was Khumal Bikash. In the first year, it was planted in 1st February 2022 and harvested in 25 May 2022. In the second year, it was planted in 8 February 2023 and harvested in 1 June 2023. All the crop management practices including irrigation, pest and disease control measures were applied as and when necessary following NARC's recommendations.

Measurements

Germination: Germination (%) was measured at 30DAT. Total numbers of plants were counted per plot and is calculated for its emergence. Ground cover that involves estimating the percentage of ground covered by the potato canopy was also visually estimated at 60 DAT. At the same date, vigor of the plant was also measured at 60 DAT by assessing the percentage of ground covered by the potato canopy, its height and ground cover. Uniformity was measured at the same time based on visual inspection of plant spacing, height, and tuber size.

Soil nutrient status: Soil pH, soil organic matter, total nitrogen, available phosphorus, available potassium, boron and zinc were measured before planting and after harvesting of the trial.

Yield and yield components: Average tuber weight was determined on the basis of total tuber weight produced from the harvest area. Harvested tubers were separated based on their sizes. Tubers weighing < 25 g) were considered under sized or unmarketable while tubers with >50g were considered oversized tubers. Similarly, as all the diseased, cracked and rotten tubers were measured at harvest were categorized as unmarketable. Total tuber yield was the sum of marketable and unmarketable sizes of the tubers. Healthy tuber with a size more than or equal to 25 g weighed using sensitive balance at harvest. Based on the weight of tubers, they were categorized into three groups. (< 25 g, 25-50 g, ≥50 g) and classified as under size, seed size, and over size tuber, respectively.

Micronutrient efficiency: In addition to yield and yield components, micronutrient efficiency was calculated by using the following formula:

Micronutrient Efficiency (ME) = Yield with Micronutrient- Yield without Micronutrient / Amount of Micronutrient applied

Data analysis: The data were analyzed using Microsoft Excel and GenStat eighteenth edition. Data were subjected to analysis of variance (ANOVA) to find out the significance of treatment effect. Means of the treatment were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Tuber size (marketable and non-marketable) and numbers

Fertilizer treatments significantly affected tuber size, but not tuber numbers. Foliar application of Zn and B produce larger sized tubers while RDF (NPK) treatment produced higher number of smaller sized tubers (Table 2). Since yield of potato is a function of number of marketable tubers per plant, weight of marketable tuber per plant, size of tuber etc. (Singh & Kathayat, 2018), increase in number of larger tuber size increases tuber yield. Although statistically not significant, total tuber number (number/ha) was greater in the treatment with soil application of Zn and B along with lime.

Tuber yield and micronutrient efficiency

Fertilizer treatments significantly affected potato total yield every year. The foliar application of Zn and B resulted to the increase in the total weight. Lenka & Das (2019) also stated that foliar application of soil application of B and Zn was found superior in increasing tuber yield. The foliar application of Zn and B increased in the weight of the large sized seed sized tubers. Foliar spray of boron increased the number of tubers per plant which might be because of the greater accessibility of boron by foliar feeding and the important role of boron on sugar transport, increasing respiration rate and cell integrity, increasing uptake of some nutrients and metabolic activities (Ali *et al.*, 2013). Similar results were mentioned in rice by (Yogi *et al.*, 2024), in chickpea (Kumar *et al.*, 2023). The micronutrient efficiency of foliar application of Zn and B is 1494 i.e., it increases 1494 kg/ha of potato tuber than the yield without B and Zn. The treatment with foliar application of Zn and B increases yield by 32.28 % than the yield with only NPK. It was followed by the soil application of Zn and B along with agriculture lime. Lenka & Das (2019) reported that the highest tuber yield (30.12 t/ha) was recorded with foliar application of 0.1% boron + 0.1% zinc along with recommended dose of fertilizer (RDF) of NPK. Dhakal (2019) suggested that foliar applications of Zn-EDTA @180 ppm at 45 DAP and 65 DAP is effective in potato production with respect to better growth and yield in Sudal, Bhaktapur. Foliar fertilization with micronutrients is proved to be an effective strategy to remove the deficiency when soil application is not beneficial or fails to adequately address the nutrient requirements of the plants (Yogi *et al.*, 2024). Tariq *et al.* (2022) evaluated different methods of application and ranked them as foliar spray > fertigation > soil dressing in term of their effectiveness towards potato yield and quality improvement. Rather than soil application, a foliar application is more effective at enhancing plant inbuilt mechanisms, plant cell homeostasis, water relations, and productivity during abiotic stresses (Pasala *et al.*,

Table 2. Effect of Zn and Boron on sizes of potato tuber, total tuber/ha, total yield (t/ha) and micronutrient efficiency.

Treatments	Under size (25-50 g) tuber yield (t/ha)	Seed size (25-50 g) tuber yield (t/ha)	Over size (≥50gm) tuber (t/ha)	Total yield (t/ha)	Micronutrient efficiency (kg yield/kg micronutrient)
RDF	4.138 ^{ab}	11.48 ^{b}	8.45 ^{d}	24.07 ^{d}	0
RDF (+ZnB)	4.252 ^{a}	12.1 ^{b}	11.05 ^{b}	27.4 ^{bc}	666
RDF (+Lime and B)	4.187 ^{ab}	12.39 ^{b}	10.45 ^{bc}	27.02 ^{bc}	590
RDF (+Lime and Zn)	3.41 ^{ab}	12.49 ^{b}	8.66 ^{cd}	24.56 ^{cd}	98
RDF (+Lime and ZnB)	3.49 ^{bc}	12.95 ^{ab}	12.36 ^{ab}	28.81 ^{b}	948
RDF (+ZnB foliar)	3.37 ^{c}	14.56 ^{a}	13.9 ^{a}	31.84 ^{a}	1494
RDF (+2% urea and 2% MoP foliar)	4.16 ^{ab}	12.89 ^{ab}	11.71 ^{b}	28.77 ^{b}	940
Mean	3.86		10.94	27.50	
F (0.05)	*	*	*	*	
LSD	0.96	2.365	2.678	3.875	
Cv%	14.9	11.1	14.6	8.4	

Table 3. Effect of Zn and boron on plant emergence, ground cover, vigor and uniformity.

Treatments	Germination (%)	Ground Cover (%)	Vigor	Uniformity
RDF (100:100:60 kg N: P_2O_5: K_2O/ha, FYM: 20t/ha)	76.3 ^{b}	63.33^{c}	2.66 ^{ab}	3.083 ^{ab}
RDF+Zinc+ Boron	82.3 ^{ab}	67. 5^{bc}	2.16 ^{c}	2.75 ^{b}
RDF+ Ag lime+ Boron	92.2 ^{a}	66.67 ^{bc}	2.5 ^{bc}	3 ^{ab}
RDF+Zinc+Ag lime	94.1 ^{a}	70 ^{abc}	2.83 ^{ab}	3.33 ^{a}
RDF+ Zinc+ Boron+ Ag lime	94.8 ^{a}	76.67 ^{a}	3 ^{a}	3.167 ^{a}
RDF+ (Zn +B) foliar spray	93.2 ^{a}	73.33^{ab}	3 ^{a}	3.417 ^{a}
RDF+ (2% Urea + 2% MOP) foliar spray	86.2 ^{ab}	71.67^{ab}	3 ^{a}	3.167 ^{a}
Mean	88.4	69.88	2.738	3.13
F (0.05)	*	*	*	*
LSD	18.52	10.464	0.5701	0.548
Cv%	12.5	8.9	12.4	10.1

Table 4. Effect of the treatments on soil nutrient status after harvesting.

Before harvesting	Soil pH	Soil TN%	P_2O_5 ppm	K_2O ppm	OC %	Boron (µg/g)	Zn (µg/g)
	6.15	**0.11**	**162.37**	**63.13**	**0.92**	**2**	**9.3**
After Harvesting (For the combined year)							
RDF (100:100:60 kg N:P_2O_5: K_2O/ha, FYM: 20t/ha	6.52	0.18	202.19	87.7	1.77	5.64	11.1
RDF+Zinc+Boron	6.58	0.13	232.06	82.4	1.90	5.81	10.27
RDF+Ag lime+Boron	6.83	0.19	231.15	87.7	1.84	3.85	9.25
RDF+Zinc+Ag lime	6.59	0.18	249.98	79.8	1.79	5.38	11.01
RDF+Zinc+Boron+Ag lime	6.59	0.18	265.19	80.7	1.87	6.02	11.80
RDF+(Zn +B) foliar spray	6.60	0.18	272.61	103.5	1.71	4.31	8.59
RDF+(2% Urea+2% MOP) foliar spray	6.41	0.15	209.79	92.9	1.51	6.55	8.40

2021). Based on these results, we can recommend foliar fertilization of Zn and B at 15-20 days interval to be significantly effective than other methods.

Plant emergence, ground cover, vigor and uniformity

The results showed that that plant emergence of potato was significantly influenced by application of B and lime . The plant emergence varied rom 94.8 to 76.3. The highest germination %, ground cover , vigor and uniformity was governed by the combined application of Zn, boron and recommended fertilizers. The highest plant emergence and ground cover was recorded with treatment T_5 (RDF + Ag lime + 2 kg B /ha and 3 kg Zn/ha as soil application) and the lowest with in the treatment T_1 (RDF).

Effect of the treatments on soil nutrient status

There is addition of soil N, soil phosphorus, soil potassium and organic carbon after fertilizer and micronutrient application. Also, the soil pH is shifted towards neutral after fertilizer and micronutrient application.

Conclusion

From the above results, application of NPK as per the recommended dosage along with the foliar application of zinc and boron (3kg Zn/ha and 2 kg B/ha) could be an effective approach to increase potato yields compared to without micronutrients. Moreover, application is more effective once they are done at 40 and 60 days of planting compared to the recommended practice with application of only NPK fertilizers and sole application of zinc and boron. This study suggest that micronutrients Zn and B could play a critical role in increasing potato yield and use efficiency would be higher once they are applied as foliar spray in two splits. Since most Nepalese soils are deficient in both Zn and B, government should encourage farmers to use micronutrients not only to increase potato yield but also to improve soil fertility.

DECLARATIONS

Author contribution

Conceptualization: R.S, KR.P, K.U, YK.G.; Methodology: R.S, KR.P, K.U, YK.G.; Software and validation: R.S, KR.P, K.U, YK.G.; Formal analysis and investigation: R.S, KR.P, K.U, YK.G; Resources: R.S, KR.P, K.U, YK.G Data curation: R.S, K.U, YK.G.; Writing-original draft preparation: R.S, KR.P, K.U, YK.G.; Writing—review and editing: R.S, KR.P, K.U, YK.G.; Visualization: R.S.; Supervision R.S, KR.P, K.U, YK.G.; Project administration: All authors have read and agreed to the published version of the manuscript.

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