Research article

EFFECT OF FOLIAR APPLICATION OF DIFFERENT NUTRIENTS ON GROWTH, YIELD, AND QUALITY OF POTATO (*Solanum tuberosum* L.) IN SANKHU, KATHMANDU, NEPAL

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Received date: 22 December 2021, Accepted date: 5 March 2022

ABSTRACT

A study was conducted from January to June 2021 in the farmer's field at Shankharapur-7, Sankhu, Kathmandu, Nepal to assess the effectiveness of the foliar application of different nutrients for potato production. The field experiment was laid out in Randomized Complete Block Design with six treatments, T_1: zinc at 560 ppm, T_2: magnesium at 0.4 %, T_3: boron at 100 ppm, T_4: calcium at 0.8 %, T_5: copper at 1 %, and T_6: control and were replicated four times. The chemicals were sprayed 30 and 40 days after planting until runoff. The highest tuber yield was obtained with the application of calcium at 0.8 % (38.57 $Mtha^{-1}$) while the lowest marketable tuber yield was obtained with copper at 1 %. The highest calcium and zinc content in potato tuber was observed with the application of calcium at 0.8 % and zinc at 560 ppm respectively. Likewise, the application of zinc increased the protein percentage in tuber by 23 % compared to the control. Thus, it can be concluded that the foliar application of calcium at 0.8 % is the most economical resulting in the highest plant growth, yield, and producing the best quality potatoes under the climatic condition of Sankhu, Nepal.

Keywords: Deficiency, management, minerals, potato

INTRODUCTION

Potato (*Solanum tuberosum* L.) belonging to the Solanaceae family is one of the most important vegetable crops. Potato contains 75 % to 80 % water, 16 % to 20 % carbohydrates, 2.5 % to 3.2 % crude protein, 1.2 % to 2.2 % true protein, 0.8 % to 1.2 % crude fats, 0.1 % to 0.2 % crude fiber, and 0.6 % vitamins (Reddy et al., 2018)is the most commonly cultivated tuber crop and fourth most important food crop in the world, after wheat, rice and maize [1]. Potato belongs to family solanaceae and genus Solanum, with a basic set of 12 chromosomes (x = 12. Favored by the diverse climatic condition, potato can be grown from 60 m to 4,000 masl all year round in Nepal (Sapkota & Bajracharya, 2018)especially those located in remote villages are inadequately informed about technical knowledge, inputs and efficient use of resources causing poor production and low productivity. Thus, the present survey aimed to examine the efficiency of resources used in potato production in Baglung District, one of the remote hilly place located in Central Himalaya. The total of 120 potato growing households was selected using simple random sampling technique from the two potato pocket in 2016. The regression coefficients of each inputs using Cobb-Douglas production function were estimated using Stata software. Our results showed that major inputs such as labor, bullock, Farm Yard Manure (FYM. At present, potato is the most stable food crop in Nepal especially in high hills behind rice, wheat, and maize, and contributes substantially to the Nepali diet (Gairhe et al., 2017). In the current scenario, the productivity of potatoes failed to meet the ever-increasing demand of people and the foliar application of nutrients can be one of the alternatives to increase the production and productivity of potatoes (Sarker et al., 2019).

In Nepal, the normal yield of crops could not be achieved despite the balanced use of NPK fertilizers due to micro-nutrient deficiency in soils. The problem of micronutrient deficiency in the soil had been observed in all three geographic regions (Andersen, 2007) high erosion rates, poverty, subsistence agriculture, and increasing cropping intensity. Agriculturally based strategies for the reduction of micronutrient malnutrition will require knowledge of the scale and spatial patterns of soil deficiencies or excesses of some elements. The present article documents current knowledge about the micronutrient status of cultivated soil in Nepal. Most studies have recorded largely the same magnitude of deficiencies in this country. Some 80 to 90% of soil samples were deficient in boron (B. These deficiencies adversely affected the crop vigor and resulted in poor yield, low-quality tubers, and lesser profits. These problems could be addressed by the application of nutrients (Ecochem, 2017). The Churia range and many areas of Nepal are predominant with sandy soil (Paneru, 2013). Foliar fertigation is 20 times more efficient in sandy soil than soil-applied fertilizers (Ecochem, 2017). Also, foliar fertigation can quickly rectify the nutrient deficiency in short-term crops as compared to soil fertilizers and that can significantly enhance the yield of potatoes (Ernest, 2016). The crops cultivated on nutrient-deficient soil led to acute diseases related to nutrient deficiency to the consumers in long run (Andersen, 2007)high erosion rates, poverty, subsistence agriculture, and increasing cropping intensity. Agriculturally based strategies for the reduction of micronutrient malnutrition will require knowledge of the scale and spatial patterns of soil deficiencies or excesses of some elements. The present article documents current knowledge about the micronutrient status of cultivated soil in Nepal. Most studies have recorded largely the same magnitude of deficiencies in this country. Some 80 to 90% of soil samples were deficient in boron (B. The nutrient content in potato tuber could also be supplemented by the foliar application of nutrients (Rahman et al., 2018). The majority of the commercial farmers reported irregular sized potatoes at harvesting. Teixeira et al. (2017) reported the effectiveness of the foliar application of boron and calcium on tuber size and quality. Rahman et al. (2018),reported the maximum yield with 560 ppm of zinc and the highest dry matter yield in the same concentration. Sarker et al., (2019) reported that three sprays of 0.1 % boric acid (at 40, 50, and 60 days after planting) produced the maximum number and yield of tubers. Yara (1976), in his experiment, reported that regular use of magnesium on an annual basis increased the yield of a crop from 1 to 10 %. This shows the importance of foliar application of nutrients as an alternative for increasing the productivity of potatoes. Under these contexts, this experiment was done to determine the effect of commercial nutrients as a foliar application on the yield and quality parameters of potatoes.

MATERIALS AND METHODS

The experiment was conducted in the farmer's field of Shankharapur-7, Sankhu, Kathmandu from January 29 to May 24, 2021. The experimental site falls in the mid-hills of Bagmati province and is at an altitude of 1348 m from the mean sea level and has a global positioning system (GPS) 27°44'56.8"N and 85°29'45.4"E. The experiment was laid out in a single factorial Randomized Complete Block Design with a total of six treatments each replicated four times. The treatments consisted of T_1-zinc (Sampurna zinc) 560 ppm, T_2-magnesium (Agroplex) 0.4 %, T_3-boron (Boromax Powder) 100 ppm, T_4-calcium (Fertimix) 0.8 %, T_5-copper (Copper sulphate) 1%, and T_6-control (water spray). The chemicals were sprayed twice at 30 DAP and 40 DAP to run-off condition.

The total experimental area was 121.68 m^2 (15.6 m × 7.8 m) with space between replication and plot 0.4 m and 0.3 m respectively. The individual plot size was 3.5 m×1.0 m. The tubers of potatoes were planted in the raised method of planting at the crop geometry of (70 × 25) cm^2. There were altogether 5 rows in each plot and 4 plants standing in a row. There were 20 plants in each plot and the inner 5 plants were selected for observation during the growing and harvesting period.

The plant height and stem diameter were measured before and after foliar spray. The canopy cover, number of leaves were recorded at 60 and 75 DAP while the number of tubers, tuber diameter, weight of tuber per hill were measured after harvesting. The zinc, calcium, and magnesium content were analyzed following the procedure mentioned by AOAC 985.35 21st Edition while the protein content was measured following the procedure mentioned by AOAC 20th 2016, 950.36,920.87. All the data collected during field and laboratory investigation were pooled, tabulated, and statistically analyzed according to the procedure of Freeman et al., (1985). Statistical packages like Microsoft Excel, R, and R-Studio were used for the analysis of different parameters recorded during the experiment. ANOVA, LSD, and DMRT tests of the parameters were done.

A composite sample of soil comprising every replication was collected from the top (0-30 cm) layer of the experimental field before tuber planting. The collected sample was then air-dried, grounded, and sieved through a 2 mm sieve and subjected to soil test. The chemical analysis of the soil was carried out following standard method (Loveland, 1997). The nitrogen content was determined using the Kjeldahl method, phosphorous content using modified Olsen's bicarbonate method, potassium content using flame photometer method, organic matter content using Walkley-Black Method, and zinc, iron, boron, copper content using atomic absorption spectroscopic method. The texture of the soil at the experimental site was loamy whereas the pH of the soil was 6.6. The nitrogen (N), phosphorus ($P_2O_{5)}$, potassium (K_2O) content of the soil was 1.6 %, 126.71 kg/ha, and 279.05 kg/ha respectively. The organic matter content of the soil was 0.06 %. The zinc, iron, boron, and copper content of the soil was recorded as 4.8 ppm, 11.03 ppm, 0.38 ppm, and 1.066 ppm respectively.

The data on weather parameters like earth temperature (^oC), average precipitation (mm), photosynthetically active radiation (Wm^{-2}), wind velocity at 2-meter (ms^{-1}), surface soil wetness, and relative humidity (%) were recorded from the database of NASA power (NASA Power, 2020). The average relative humidity recorded during the crop duration was 56.6 % while the maximum relative humidity recorded was 77.62 %. The mean temperature recorded during the crop duration was 17.64 ^{o}C while the maximum temperature recorded was 26.5 ^{o}C. The average precipitation recorded was 1.58 mm with maximum precipitation of 17.84 mm.

RESULTS AND DISCUSSION

Plant height

The results showed that the effect of different nutrients on plant height was significant at all growth stages except 30 days of planting (Table 1). The non-significant result in height of the plant at 30 DAP signified that there was no variation among the plants before treatment and all the variations afterward were due to the treatments. At 45 DAP, plant height was the highest (16.75 cm) with the foliar application of zinc and the least (8.75 cm) with the foliar application of copper. Plant height with zinc application (16.75 cm) was significantly at par with the application of magnesium (15.95 cm), calcium (15.65 cm), and boron (15.40 cm) as compared with control (13.95 cm). A similar pattern was observed at 60 DAP and 75 DAP (Table 1). The foliar application of different nutrients like zinc, magnesium, calcium, and boron contributed better towards plant height in comparison to control. The increase in plant height by these nutrients may be due to the role of nutrients in the synthesis of auxin and plant's metabolism. These results are following Blodgett et al. (1933) The least plant height observed with the copper application may be due to calcium toxicity (Yruela, 2005). The post-application symptoms showed necrosis, leaf curling, and stunting which were the characteristic feature of copper toxicity (Macnicol & Beckett, 1985).

Table 1. Effect of foliar application of different nutrients on plant height of potato at Sankhu, Kathmandu, Nepal

Treatment (Tn)	Plant height (cm)			
	30 DAP	45 DAP	60 DAP	75 DAP
Zn	4.825	16.75^{a}	45.45^{a}	64.35^{ab}
Mg	4.675	15.95^{a}	44.20^{ab}	64.63^{ab}
B	4.925	15.40^{ab}	42.80^{ab}	64.05^{ab}
Ca	4.975	15.65^{ab}	45.45^{a}	67.0^{a}
Cu	4.925	8.75^{c}	27.15^{c}	54.2^{c}
Control	4.925	13.95^{b}	41.92^{b}	61.57^{b}
SEm (±)	0.1312	0.61	1.299	1.68
LSD (0.05)	0.1..15	1.177	3.91	5.07
F-value	NS	<0.001***	<0.001***	<0.01**
CV (%)	5.38	8.36	6.34	5.37
Mean	4.87	14.41	40.98	62.63

Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means followed by common letter(s) within a column are not significantly different among each other based on DMRT at 0.05 level of significance.

Stem diameter

The analysis of variance regarding the stem diameter revealed that differences in stem diameter among different treatments were statistically significant at all growth stages except at 30 days of planting (Table 2). The non-significant result regarding the stem diameter of the plant at 30 DAP signified that there was no variation among the plants before treatment and all the variations afterward were due to the treatments. At 45 days of planting, the maximum stem diameter (8.61 mm) was observed with the application of zinc and boron while the least stem diameter (4.93 mm) was observed with copper spraying. Stem diameter at 60 DAP and 75 DAP followed more or less similar patterns as that of 45 days of planting (Table 2). Foliar application of zinc, calcium, boron, and magnesium created favorable condition for increment in stem diameter compared to control. These results may be due to the increment in chlorophyll content of leaves, improvement in photosynthesis which intensified the assimilating activity of the whole plants and ultimately increased the stem diameter (Tripathi et al., 2015). Similar results were observed by Singh et al. (2014). The reason for least stem diameter with the copper treatment may be due to copper toxicity (Yruela, 2005).

Table 2. Effect of foliar application of different nutrients on stem diameter of potato at Sankhu, Kathmandu, Nepal

Treatment (Tn)	Stem diameter (mm)			
	30 DAP	45 DAP	60 DAP	75 DAP (mm)
Zn	4.075	8.61 [a]	11.17 [a]	12.06 [a]
Mg	4.065	8.19 [a]	11.19 [a]	11.21 [a]
B	4.052	8.61 [a]	11.17 [a]	11.51 [a]
Ca	4.073	8.55 [a]	11.08 [a]	11.25 [a]
Cu	4.072	4.93 [b]	8.24 [b]	8.65 [b]
Control	4.05	8.0 [a]	10.84 [a]	11.23 [a]
SEm (±)	0.0332	0.42	0.351	0.601
LSD (0.05)	0.1002	1.29	1.05	1.81
F- value	NS	<0.001***	<0.001***	<0.05*
CV (%)	1.6	10.99	6.62	10.95
Mean	4.064	7.81	10.61	10.98

Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means followed by common letter(s) within a column are not significantly different among each other based on DMRT at 0.05 level of significance.

Leaf number and Canopy cover

The number of leaves and canopy cover was found to be significantly different in different treatments compared to the control (Table 3). Foliar fertilization with zinc, magnesium, boron, and calcium significantly improved the leaf number and canopy cover which may be due to the increase in cytokinin content of the plant which led to the development of new leaves and substantial increase in vegetative growth. Similar significant increase in the leaf number and canopy cover were observed with the application of calcium and zinc by Moinuddin et al. (2017) as well as Manna and Mait (2016). The copper application showed a negative response towards leaf number and canopy cover which confirmed the findings of Yruela (2005).

Table 3. Effect of foliar application of different nutrients on leaf number of potato at Sankhu, Kathmandu, Nepal

Treatment (Tn)	Leaf number		Canopy cover (cm)	
	(45 DAP)	(60 DAP)	(45 DAP)	(60 DAP)
Zn	30.92[a]	48.20[a]	54.62 [a]	67.9 [a]
Mg	30.82 [a]	47.95[a]	53.0 [a]	64.0 [ab]
B	30.27 [ab]	47.70[a]	52.67 [a]	68.5 [a]
Ca	30.84 [a]	48.75 [a]	55.62 [a]	69.6 [a]
Cu	22.48 [c]	33.90[c]	41.67 [b]	52.28 [c]
Control	29.0 [b]	43.15[b]	50.67 [a]	59.40[bc]
SEm (±)	0.497	0.623	1.72	2.66
LSD (0.05)	1.499	1.878	5.21	8.03
F value	<0.01**	<0.01**	<0.001 ***	<0.001 ***
CV (%)	3.42	2.36	6.72	8.37
Mean	29.05	44.94	51.42	63.63

Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means followed by common letter(s) within a column are not significantly different among each other based on DMRT at 0.05 level of significance.

Yield attributes

The highest tuber weight per hill (675.8 g) was observed with the application of calcium while the minimum tuber weight per hill (457.5 g) was observed with copper spraying. The maximum weight of tuber with calcium fertilization may be due to the role of calcium in influencing tuberization by altering the hormonal balance at the stolon tip. Hamdi et al. (2015) observed that the application of additional calcium nitrate fertilizers increased tuber weight, dry matter, and tuber size.

The analysis of variance revealed that yield was statistically significant among different treatments (Table 4). The maximum yield (38.57 $Mtha^{-1}$) was observed with the application of calcium while the least yield (26.14 $Mtha^{-1}$) was observed with copper spraying. The maximum yield observed with the application of calcium nitrate fertilizers may be due to the role of calcium in the betterment of vegetative growth parameters and tuberization process. These results are as per the findings of El-Hadidi et al. (2017)two field experiments were conducted at Kafr Bosat Village, Talkha District, Dakahlia Governorate, Egypt (Latitude 30° 43 ' 22.01\" N, Longitude 30° 16' 44.50\" E. The least tuber yield observed with the application of copper may be due to copper toxicity. The level of copper in the plant may have reached toxic concentration after the spraying of copper at 30 DAP and 40 DAP. The plant showed negative responses after the spraying of chemicals-like stunting, chlorotic patches which were indicators of copper toxicity (Yruela, 2005). Copper concentration above optimal range interfered with the important cellular process of plants such as respiration and photosynthesis (Clarkson, 1996). He also reported that copper toxicity interfered with the biosynthesis of the photosynthetic machinery, modified the pigment and protein composition of the photosynthetic membranes, and because of these modifications, alteration of PSII membrane fluidity was observed. This series of modifications hampered the vegetative growth as well as the yield of potatoes.

Table 4. Effect of foliar application of different nutrients on yield attributes of potato at Sankhu, Kathmandu, Nepal

Treatment (Tn)	Weight of tuber per hill (g/ hill)	Number of tubers per hill	Diameter of tuber (cm)	Yield ($Mtha^{-1}$)
Zn	625.3^{b}	9.25^{ab}	2.93^{ab}	35.72^{b}
Mg	610.7^{bc}	9.75^{a}	2.87^{ab}	34.86^{b}
B	582.5^{c}	8.00^{bc}	2.86^{b}	33.29^{c}
Ca	675.8^{a}	7.25^{cd}	3.01^{a}	38.57^{a}
Cu	457.5^{e}	5.20^{e}	2.62^{c}	26.14^{e}
Control	547.5^{d}	6.25^{de}	2.68^{c}	31.28^{d}
SEm (±)	0.00834	0.496	0.128	0.4772
LSD (0.05)	0.0251	1.4953	0.0425	1.438
F- value	<0.01**	<0.01**	<0.01**	<0.01**
CV (%)	2.86%	13.02%	3.00%	2.865%
Mean	582.9	7.61	2.83	33.30

Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means followed by common letter(s) within a column are not significantly different among each other based on DMRT at 0.05 level of significance.

Qualitative parameter

The analysis of variance showed that the calcium content, zinc content, magnesium content, and protein percentage in tuber after harvesting were statistically significant with different treatments (Table 5). The highest calcium content in the tuber (3.8 mg/100g) was observed with the application of calcium which shows that foliar spray with calcium contributed positively to the calcium content of the tuber. The highest magnesium content in potato tuber (21.5 mg/100g) was observed with the application of magnesium and these results show conformity to the findings of Koch (2018). The maximum zinc content in potato tuber (0.4 mg/100g) was observed with the application of zinc (Table 5). Banerjee et al. (2017) and Mousavi et al. (2007) also reported maximum zinc content on tuber with the foliar application of zinc as compared to control. The maximum protein content on potato tuber (2.6 %) was observed with the application of zinc while the lowest protein content (2 %) was observed with control. In this study, only zinc was enough to achieve the highest protein concentration in potato tuber which confirm to the findings of White et al. (2012).

Table 5. Effect of foliar application of different nutrients on quality attributes of potato tuber at Sankhu, Kathmandu, Nepal

Treatment (Tn)	Calcium (mg/100g)	Magnesium (mg/100g)	Zinc (mg/100g)	Protein (%)
Zn	3.4^{b}	20.6^{b}	0.4^{a}	2.6^{a}
Boron	3.1^{c}	20^{c}	0.26^{d}	2.4^{bc}
Mg	2.3^{e}	21.5^{a}	0.29^{c}	2.5^{ab}
Cu	2.2^{f}	19.8^{c}	0.26^{d}	2.3^{c}
Calcium	3.8^{a}	18.4^{d}	0.35^{b}	2.1^{d}
Control	2.6^{d}	15.6^{e}	0.34^{b}	2^{d}
SEm (±)	0.0211	0.0806	0.0056	0.0365
LSD (0.05)	0.0635	0.243	0.0169	0.110
F- value	<0.05	<0.05	<0.01	<0.01
CV (%)	1.45%	0.834	3.55	3.15
Mean	2.9	19.31	0.316	2.31

Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means followed by common letter(s) within a column are not significantly different among each other based on DMRT at 0.05 level of significance

Economic analysis

The economics was worked out taking into consideration, the cost of production for each treatment, the corresponding yield with prevalent prices per unit output. Among different treatments, the highest B: C ratio was observed with the application of calcium (2.31) while the lowest B: C ratio was recorded with copper (1.51). A detailed description of the cost of production, the net return, and the B: C ratio is mentioned in Table 6.

Table 6. Effect of foliar application of nutrients on the economics of potato production at Sankhu, Kathmandu, Nepal

Treatment	Chemicals applied	Total cost of production (NRs. /kattha)	Gross return (NRs. /kattha)	Net return (NRs. /kattha)	B:C ratio
Zn	Zn- EDTA	20380	41673.3	21293.3	2.04
Mg	Magnesium Sulphate	19630	40670.0	21040.0	2.07
B	di-sodium octaborate tetrahydrate	19460	38838.3	19378.3	1.99
Ca	Calcium nitrate fertilizers	19480	44998.3	25518.3	2.31
Cu	Copper Sulphate crystals	20180	30496.7	10316.7	1.51
Control	Water	19180	36493.3	17313.3	1.90

CONCLUSION

The highest plant growth parameters (plant height, number of leaves, canopy cover, and stem diameter) and yield were observed with the foliar application of calcium making it the most suitable nutrient for potato production in Sankhu, Kathmandu. The application of copper reduced the plant height, tuber diameter, and yield making it unsuitable for potato in Sankhu, Kathmandu. The maximum protein percentage in potato tuber was observed with the application of zinc making it the most nutritious compared to other treatments. The application of calcium was the most economical compared to other treatments in Sankhu, Kathmandu.

ACKNOWLEDGEMENTS

It is our pleasure to acknowledge the contribution made by various people during this research. We would like to extend our sincere gratitude to PMAMP, Agriculture Knowledge Centre; Lalitpur and Agriculture and Forestry University, Rampur for providing me this platform. We would like to extend our profound sense of gratitude to the site supervisor, Mr. Krishna Bhadra Adhikari (Office Chief, AKC, Lalitpur), for his support, encouragement, and regular supervision of this study.

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