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Performance of potato (*Solanum tuberosum* L.) at different phosphorous levels and mulch in Bajura, Nepal

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ABSTRACT

Nutrient is one of the vital factors that helps in the growth of crops. A field experiment was conducted to study the performance of potatoes at the different phosphorous levels and mulch from February to June 2021 in Dhamkane, Bajura district, Nepal. The experiment was arranged in two factorial RCBDs with 3 replications and 8 treatments. Bajura local variety was used. Four levels of phosphorous 0, 50, 100, and 150 kg ha^{-1} were used and for mulching, silver on black plastic mulch and no mulch (control) was used. It was observed that both mulching and phosphorous levels influenced the growth and yield of potatoes. Plant height (39.90 cm), number of leaves (439.98) was significantly highest in silver in black plastic mulch whereas haulm number was significantly highest in no mulch condition. In the same way, significantly highest plant height (44.36 cm), haulm number (4.15), and the number of leaves (442.10) were found on 100 kg ha^{-1} P level. The main effect of mulching and phosphorous level was found to increase the yield but no interaction was observed. The highest average tuber weight, yield plant^{-1} and number of tubers plant^{-1} were found on silver in black plastic mulch. Average tuber weight is highest at 150 kg ha^{-1} phosphorous level. The number of tuber plant^{-1} was highest for silver on black plastic mulch and 100 kg ha^{-1}. Marketable and non-marketable tubers were significantly highest at silver on black plastic (8.55 and 3.1) and 100 kg ha^{-1} (10.45 and 3.46). The overall performance was superior in silver on black plastic mulch and 100 kg ha^{-1} P level with significant B: C ratio.

Keywords: Phosphorous, Bajura, nutrient, local variety, potato, mulching

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1 Introduction

Potato (*Solanum tuberosum* L.) is the annual plant of Solanaceae family that is grown for its starchy edible tubers. Potato is native to South America and spread worldwide (Samad et al., 2015). In terms of consumption, potato is the third most important crop after rice and wheat (CIP, 2020). 370.43 million tons of potatoes are produced from 17.34 million ha of land (FAOSTAT, 2019). The cultivation history of potatoes in Nepal is as old as in Europe (Rhoades, 2008). Potatoes are widely grown in Nepal, from below 100 m altitudes in the south to as high as 4000 m in the northern mountains, and are major significant food sources in Nepal (Upadhaya et al., 2020). The crop has the ability to produce maximum quantity within minimum time and with the use of minimum water (Abraham et al., 2014). It is a good source of food that contains carbohydrates, protein, vitamins, and minerals. Nepal is one of the top twenty countries where potato contributes substantially to the human diet. It is used as a subsidiary vegetable in Terai and major staple food in Hill and Mountain Region in Nepal (Subedi et al., 2019). The total area under potato cultivation, production, and yield in Nepal is 193,997 ha, 3,112,947 mt, and 16.05 mt ha^{-1}, respectively (MOALD, 2020).

The demand for nitrogen (N), phosphorous (P), and potassium (K) are very high in potatoes. It is a soil exhaustive crop. Phosphorous and nitrogen are critical determinants for plant growth and productivity (Kahsay, 2019). Phosphorus is especially important for early plant development, increasing early crop growth, and rapid tuber growth of potatoes and is also responsible for energy transfer which is necessary for metabolic processes within the plant (Mishra, 2018). The main effect of P fertilizer significantly affected the day to reach flowering, attain physiological maturity, number of stems and biomass yield of the plant (Misgina, 2016). The levels of NPK imparted a significant effect on the fresh weight of leaves and stems at each successive stage of crop growth where increasing levels of NPK increased the plant height by 15-42 percent (Adhikari, 2014). Balemi (2010) in his trial found that low P supply on the growth of potato genotype reduced shoot dry matter yield, relative growth rate, leaf number, whole plant relative leaf expansion rate, total leaf area plant^{-1}, plant height and net assimilation rate of P-inefficient genotype, more than that of the P-efficient genotypes. Adequate P is essential for optimizing tuber yield, solids content, nutritional quality and resistance to some diseases (Rosen et al., 2014). Rosen and Bierman (2008) in their experiment on potato yield and tuber set as affected by phosphorous fertilization observed that P treatments significantly affected the total fresh weight of tubers, shoots and tuber number and moist treatment gave a significantly higher yield of both tuber and tuber number compared to the dry treatment.

Mulching is an effective method of altering the plant micro-environment to increase crop yield (Li et al., 2018). It plays an important role in ameliorating soil and environmental stresses of most tropical crops (Manrique, 1995). The mulch increases available P, K and organic carbon and it may enhance crop growth and yield (Kar and Kumar, 2007). Mulch treatments substantially advanced plant emergence compared to plants in bare soil apparently in response to higher soil temperatures under the mulches during the first 3 weeks from planting (Collins, 1976). Majumder et al. (1970) also reported a positive result on mulching than non-mulching on plant height, number of the shoot, and leaf number. The application of organic mulches contributed to yield increment, weed control, erosion, and sustaining soil productivity by improving physical and biological soil conditions (Ibeawuchi et al., 2015).

2 Materials and Methods

2.1 Experimental site

A farmer's field was selected in Dhamkane, Badimalika municipality-7, Bajura, Nepal at an altitude of 2200 masl for the study. The site has 81.551571° E longitude and 29.456021° N latitude. It lies in Sudurpaschim province of Nepal. The samples of soil were taken from the experimental field with the help of soil sampling auger at different spots randomly from the depth of 20-25 cm. The analysis of sample was done in lab at Soil and Fertilizer Testing Laboratory, Sundarpur, Nepal. The data regarding the soil is given below in Table 1.

Table 1. Soil chemical properties of Dhamkane, Badimalika Municipality, Bajura, 2021

Chemical properties	Content	Rating
Soil pH	6.96	Neutral
Soil Organic Matter (%)	6.54	High
Total Nitrogen (%)	0.33	High
Available P2O5 (kg/ha)	10.89	Low
Available K2O (kg/ha)	276	Medium
Soil texture	Silty loam	

2.2 Plant materials

Medium size tubers (45-50 g seed tuber) of Bajura local variety were sown on February 25th, 2021. The spacing maintained was 60 × 20 cm. The field was prepared by one deep plowing followed by three light plowing and harrowing. Since the NPK requirement for potato is 100: 100: 60, NK were applied as per the recommendation and P was applied (0, 50, 100, 150 kg ha^{-1}) as per experimental design. All the fertilizers were provided as a basal dose.

2.3 Experimental design

The experiment was comprised of two factors, *viz.* mulching (silver on black plastic mulch (M1) and no mulch (M2)) and levels of phosphorus (P) (0, 50, 100, and 150 kg P ha^{-1}). The experiment was designed in Randomized Complete Block Design (RCBD) with 3 replications.

2.4 Data observation

Different growth and yield parameters data were measured from 5 randomly selected plants from each plot excluding border plant. Data relating to economics were also calculated by using standard technique.

2.5 Statistical analysis

All the acquired data were entered in MS- excel and analyzed on R-Studio. Duncan's Multiple Range Test (DMRT) was conducted for mean separations by selecting 5% level of significance (Shrestha, 2019; Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Effect of different P levels and mulch on growth parameters

The results of plant height, haulm number and the number of leaves plant^{-1} as influenced by mulching and different phosphorous level is given in Table 2. A significant effect can be observed in all the observations. Mulching and phosphorous levels significantly influenced the plant height at all dates of observations. Plant height was significantly highest in silver on black plastic mulch than in no mulch in all observations. Bhatta et al. (2020), Ahmed et al. (2017) and Mahmood et al. (2002) reported a similar result with maximum height in plastic mulch. The vigorous growth of plant height in mulch conditions may be due to better weed control, moisture conservation and better micro-climate inside mulch. Phosphorous level @100 kg ha^{-1} resulted in the highest height of any other in 45 DAS. At 75 DAS, the highest plant height was observed at 100 kg ha^{-1} which was statistically similar to 150 kg ha^{-1}. Phosphorus boosts the metabolic activity of the plants during the early growth stages that encourage stem elongation (Ekelof, 2014).

Haulm number plant^{-1} was significantly influenced by mulching and phosphorous level on all dates of observations. At 45 DAS, the highest haulm number plant^{-1} was found in no mulch condition and the lowest one on silver on black plastic mulch which remained same till 75 DAS. Wang and He (2012) reported the negative effects of mulching included a lower emergence and both, tuber yield and water use efficiency (WUE) decreased with increases in mulch duration and suggested removing plastic mulch early. Number of haulm might depends on sprouting in potato seed but not on mulching which coincide with the finding of Kabir et al. (2021). At 45 DAS, the highest haulm number was observed at 0 kg ha^{-1} and the lowest at 150 kg ha^{-1}. These observations changed and the maximum haulm number was observed in 100 kg ha^{-1} and lowest in 150 kg ha^{-1} at 75 DAS. Aarakit et al. (2021) reported a higher haulm number where P was applied at 30, 60, and 90 kg ha^{-1}. Misgina (2016) and Rosen and Bierman (2008) also reported an increase in stem number plant^{-1} with increased P fertilizers.

Mulching and phosphorous level significantly influenced the number of leaves plant^{-1} at all dates of observations. The number of leaves plant^{-1} was significantly highest in silver on black plastic mulch and lowest in no mulch which remained the same for all dates of observation from 45 DAS to 75 DAS. Jenni et al. (1996) and Ruíz-Machuca et al. (2014) observed and verified that black and silver plastics are more effective in an increase of leaf area than on bare land. Sarkar et al. (2019) in their research on onion, where different growth characteristics were observed by different colored plastic mulching found higher plant height, the number of leaves plant^{-1} and fresh root biomass on silver mulching. They might be due to the increase in mean soil temperature as the use of colored plastic mulch creates a positive relationship between mean soil temperature and growth characteristics (Torres-Olivar et al., 2016). Similarly, a significantly higher number of leaves plant^{-1} was observed in 100 kg ha^{-1} as compared to 0 kg ha^{-1} and 150 kg P ha^{-1} at 45 DAS. At 75 DAS, the highest number of leaves plant^{-1} was observed at 100 kg P ha^{-1} which was at par with 150 kg plant^{-1} ha^{-1} and significantly higher than 50 kg ha^{-1} and 0 kg P ha^{-1}.

3.2 Effect of different P levels and mulch on yield parameters

The result of average tuber weight (g), tuber yield plant^{-1} (g), and the number of tubers plant^{-1} as influenced by mulching and different phosphorous levels are given in Table 3. A significant effect was observed in all the parameters.

Mulching had a non-significant effect on average tuber weight but significant (<0.05) at different phosphorous levels. The silver on black plastic mulch gave the highest average tuber weight (58.28 g) and the lowest in no mulch. Phosphorous level @ 150 kg ha^{-1} gave the highest average tuber weight (66.92 g) and the lowest on no mulch. Bhatta et al. (2020) reported a higher average tuber weight on perforated black plastic mulch. Belachew (2016) reported that application of phosphorous highly significantly increased average tuber weight which could be due to more foliage and leaf area and a higher supply of photosynthesis, which helped in producing bigger tubers, hence resulting in higher yields.

Similarly, mulching had a significant effect (<0.01) and phosphorous level had a significant effect (<0.05) on tuber yield plant^{-1}. The silver on black plastic mulch gave the highest tuber yield plant^{-1} (564.02 g) and the lowest in no mulch condition. Phosphorous level @ 100 kg ha^{-1} gave the highest tuber yield plant^{-1} (575.16 g) and the lowest one in no mulch. The increase in tuber yield plant^{-1} is might be due to higher P fertilizer and micro-climate due to mulch as it increases the number of tubers which is similar to the finding of (Shrestha et al., 2020). Mona et al. (2012) also reported that NPK (120:80:100) application increased significantly the tuber yield plant^{-1} and the number of tubers plant^{-1}.

The number of tuber is found to be highly significant and influenced by mulching and level of phosphorous. The maximum number of tubers plant^{-1} was found in silver on black plastic mulch (11.83) and the minimum in no mulch (7.47). In phosphorous, the maximum number of tuber was found on 100 kg ha^{-1} (13.16) and the minimum on control 150 kg ha^{-1} (7.18)

Table 2. Influence of mulching and phosphorus levels on plant height, haulm number and number of leaves plant^{-1} of potato in Dhamkane, Badimalika municipality, Bajura in 2021

Treatment	Plant height (cm)			Haulm number plant^{-1}			Number of leaves plant^{-1}		
	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS
Mulching									
Silver on black plastic	13.41 a	28.15 a	39.90 a	2.83	3.11b	3.65 a	52.15 a	120.31 a	439.98 a
No mulch	8.18 b	20.06 b	36.96 b	3.07	3.73a	4.08 b	33.85 b	79.55 b	257.16 b
SEm (±)	0.88	0.85	1.1	0.14	0.12	0.09	3.94	7.88	24.61
LSD	1.9***	1.83***	2.36*	ns	0.26***	0.19**	8.45***	16.92***	52.78***
CV (%)	20.17	8.7	7.03	12.03	8.82	5.85	22.44	19.33	17.3
P level (kg ha^{-1})									
0	11.15 ab	20.75 c	27.08 c	3.28 a	3.43 a	3.75 b	38.96 b	64.33 c	177.16 c
50	9.93 b	22.98 bc	39.00 b	2.93 ab	3.60 a	3.83 b	37.60 b	99.26 b	355.83 b
100	13.05 a	27.46 a	44.36 a	3.1 a	3.75 a	4.15 a	56.85 a	137.70 a	442.10 a
150	9.06 b	25.23 ab	42.56 a	2.5 b	2.91 b	3.58 b	38.60 b	98.43 b	418.00 ab
SEm (±)	0.62	0.6	0.78	0.1	0.08	0.06	2.78	5.57	17.4
LSD	2.69*	2.59***	3.35***	0.44*	0.37**	0.27**	11.95*	23.93***	74.64***
CV%	20.17	8.7	7.03	12.03	8.82	5.85	22.44	19.33	17.3
Grand mean	10.8	24.1	38.43	2.95	3.42	3.82	43.04	99.93	348.27

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; DAS, Days After Sowing; ***= highly significant at 0.001; **=significant at 0.01; *=significant at 0.05

Table 3. Influence of mulching and phosphorus levels on tuber weight, tuber yield plant^{-1} and number of tubers plant^{-1} in Dhamkane, Badimalika municipality, Bajura in 2021

Treatment	Tuber weight (g)	Tuber yield plant^{-1} (g)	Number of tubers plant^{-1} (g)
Mulching			
Silver on black plastic	58.28	564.02 a	11.83 a
No mulch	47.36	410.11 b	7.47 b
SEm (±)	5.09	44.22	0.17
LSD	ns	94.84**	0.38***
CV (%)	23.64	22.23	4.53
P level (kg ha^{-1})			
0	46.28 a	385.95 b	7.56 c
50	47.26 b	437.51 ab	10.70 b
100	50.82 b	575.16 a	13.16 a
150	66.92 b	549.64 a	7.18 c
SEm (±)	3.6	31.26	0.12
LSD	15.46 *	134.13*	0.54***
CV%	23.64	22.23	4.53
Grand mean	52.82	487.06	9.65

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; ***= highly significant at 0.001; **=significant at 0.01; *=significant at 0.05

Table 4. Influence of mulching and phosphorus levels on number of small and large size tubers plant^{-1} in Dhamkane, Badimalika municipality, Bajura in 2021

Treatment	Large size tuber (>50 g)	Small size tuber (<50 g)
Mulching		
Silver on black plastic	8.55 a	3.1 a
No mulch	6.83 b	2.24 b
SEm (±)	0.21	0.1
LSD	0.45***	0.23***
CV (%)	6.75	10.06
P level (kg ha^{-1})		
0	5.8 d	2.31 c
50	7.9 b	2.88 b
100	10.45 a	3.46 a
150	6.61 c	2.01 c
SEm (±)	0.14	0.07
LSD	0.64***	0.33***
CV%	6.75	10.06
Grand mean	7.69	2.67

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; ***= highly significant at 0.001

which was statically similar to 150 kg ha^{-1} (7.56). The increase in tuber number might be due to adequate available nutrients as phosphorous resulted in vigorous root growth and nutrient uptake which coincide with the finding (Amare and Desta, 2021).

Here, the large size and small size tubers were considered marketable and non-marketable tubers, respectively and graded on the basis of tuber weight (g). The maximum number of large size tubers (8.55) and small-sized tubers (3.1) plant^{-1} was found in silver on black plastic mulch.

Table 5. Interaction effect of mulching and phosphorus levels on number tubers plant^{-1} in Dhamkane, Badimalika municipality, Bajura in 2021

P level (kg ha^{-1})	Number of tubers plant^{-1}	
	Silver on black plastic	No mulch
0	8.43d	6.70f
50	15.10b	6.3f
100	16.26a	10.06c
150	7.53e	6.83ef
LSD	0.76***	
SEm (±)	0.08	

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; ***= highly significant at 0.001

In phosphorous, the maximum number of large size tubers was found in 100 kg ha^{-1} (10.45) and the maximum number of small size tubers was found on 100 kg ha^{-1} (3.46). The greater number of both large and small tubers might be due to the unequal nutrient availability and climatic condition. Rosen and Bierman (2008) reported no significant effect on marketable tuber yield as although P fertilizer application increased total tuber yield as it increased the number of undersized tuber as P application rate increased which was contradicted by Belachew (2016) who confirmed that application of high rate of phosphorous significantly increased the marketable tuber yield per hectare. It is also supported by the fact that phosphorous perform structural elements forming part of a macromolecular structure such as (DNA and RNA) and in phospholipids of cell membranes (Marschner, 1995). The number of large and small size tubers plant^{-1} as affected by different phosphorous levels and mulching in potatoes is presented in Table 4.

The interaction was observed in the average number of tubers plant^{-1} and marketable and non-marketable tubers. In an average number of tubers plant^{-1}, the interaction effect was found highly significant in silver on black plastic with 100 kg ha^{-1} (16.26) and the lowest on no mulch at 50 kg ha^{-1} which was statically at par with no mulch at 0 kg ha^{-1} (6.70) (Table 5). Large size and small size tubers were graded on the basis of their weight at greater or less than 50 g. For large size tuber, the interaction effect was found highly significant in silver on black plastic with 100 kg ha^{-1} (11.86) and the lowest on no mulch at 50

Table 6. Interaction effect of mulching and phosphorus levels on number of small and large size tubers plant^{-1} in Dhamkane, Badimalika municipality, Bajura in 2021

P level (kg ha^{-1})	Number of large and small size tubers plant $^{-1}$			
	Large size tuber (>50 g)		Small size tuber (<50 g)	
	Silver on black plastic	No mulch	Silver on black plastic	No mulch
0	5.36e	6.23de	2.46cd	2.16d
50	10.43b	5.36e	3.46a	2.30d
100	11.86a	9.03e	3.53a	3.40ab
150	6.53d	6.70d	2.93bc	1.10e
LSD	0.90***		0.47***	
SEm (±)	0.1		0.05	

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; ***= highly significant at 0.001

Table 7. Economic of potato production as influenced by under different phosphorous level in Dhamkane, Badimalika municipality, Bajura in 2021

Treatment	Total cost of cultivation (NRs. ha^{-1})	Gross return (NRs. ha^{-1})	Net return (NRs. ha^{-1})	B:C ratio
Mulching				
Silver on black plastic	362200a	998521.7a	636321.7a	2.75a
No mulch	318250b	683986.7b	365736.7b	2.14b
SEm (±)	-	68199.46	68178.69	0.19
LSD	-	146273.3***	146228.7**	0.41**
P levels (kg ha^{-1})				
0	333300d	643186.7c	309886.7c	1.90b
50	337800c	791773.3bc	453973.3bc	2.32ab
100	342600b	1014090a	671490.0a	2.92a
150	347200a	915966.7ab	568766.7ab	2.62a
SEm (±)	-	48224.3	48209.61	0.13
LSD	-	206861.7*	206798.7*	0.58*
CV%	-	19.85	33.33	19.33
Grand mean	340225	841254.2	501029.2	2.44

Values are means. Means followed by common letter(s) within column are non- significantly different based on DMRT at P=0.05. LSD, Least Significant Difference; SEm, Standard Error of Mean; CV, Coefficient of Variation; ***= highly significant at 0.001; **=significant at 0.01; *=significant at 0.05

kg ha^{-1} which was statically similar with silver on black plastic mulch at 0 kg ha^{-1} (5.36). For small size tuber, the interaction effect was found highly significant in silver on black plastic with 100 kg ha^{-1} (3.53) followed by 50 kg ha^{-1} in silver n black plastic mulch and lowest on no mulch at 150 kg ha^{-1} (1.10). The interaction effects of mulching and different phosphorous level on numbers of tuber plant^{-1} and numbers of large size and small size tuber plant^{-1} is given below in Table 6.

3.3 Economic analysis

The economic analysis as influenced by mulching under different phosphorous levels is shown in Table 7. The Benefit Cost (BC) ratio is significantly (<0.01) influenced by mulching with the highest BC ratio seen on silver on black plastic mulch (2.75) and the lowest on control (2.14). Similarly, BC ratio is significantly (<0.05) influenced by different phosphorous levels with the highest BC ratio was seen on 100 kg ha^{-1}(2.92) and the lowest on control (1.90). The highest gross return, net return and highest BC ratio was obtained on silver on black plastic mulch and 100 kg ha^{-1} P level. Though cost was more under mulching, the profit was highest under it. Overall, the mulch and phosphorous found to be economic and profitable.

4 Conclusion

The result revealed the mulching to be effective in accelerating the vegetative growth as well as the yield of potatoes. Hence, it is concluded that silver on black plastic mulch with 100 kg ha^{-1} phosphorous level proved to be effective and increased the tuber yield with a promising B: C ratio, contributing to profitability.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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