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RESEARCH ARTICLE

IMPACT OF PLASTIC MULCH ON THE GROWTH AND PRODUCTIVITY OF POTATO VARIETIES (*SOLANUM TUBEROSUM L.*) IN PANCHTHAR, NEPAL

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ABSTRACT

From February to June 2022, a field experiment was carried out in Panchthar, Nepal, with the aim of determining the productivity and growth of potato types with and without plastic mulch. In both plastic-mulch and no-mulch environments, four potato varieties—Janakdev, Baijani, Betaay, and Jhyalay—were assessed. With three replications, the treatments were set up in a two-factorial randomized complete block design (RCBD). The experiment's conclusion showed that plastic mulch and Jhyalay produced higher plant growth. This might be due to better aeration and optimum soil temperature in the root zone of plants, better soil water retention through plastic mulch that increases effective rainfall, and available soil moisture for plant growth. Moreover, the highest tuber yield was observed in Betaay (28.13 t ha-1), followed by Janakdev and Jhyalay. The higher tuber yield in Betaay was due to the higher tuber yield per plot. Similarly, higher yields in plastic mulch were due to the increased number and weight of tubers per plot. The cultivar Betaay had the highest yield, gross return, net return, and B:C ratio; Jhyalay followed next. Hence, Betaay and Jhyalay were the most suitable varieties of potato for Panchthar-like climates for improving productivity and profitability. Despite the fact that plastic mulch produced a larger yield, its net return and B:C ratio were statistically lower than those of no mulch. The reason for this could be the high production costs.

KEYWORDS

Potato, Mulch, Variety, Temperature, Yield

1. INTRODUCTION

The potato, or *Solanum tuberosum L.*, is a major vegetable crop in the Solanaceae family. Fourth in value globally after wheat, rice, and maize, potatoes (*Solanum tuberosum L.*) were the first food crop that could not be considered an actual cereal. In the Nepalese hills, it is also considered one of the primary crops. It is also known as Alu in Nepal. It is also considered one of the major cash crops that are grown to fulfill food demand and improve the living standards of farmers (ShiJie, 2011). In Nepal, the average annual per capita potato consumption is 29.9 kilograms (CBS, 2019). In Nepal's hill and mountain regions, it is a main food; however, in the Terai region, it is used as a supplement vegetable (Subedi et al., 2019). The characteristics and diversity of consumption forms are driving up demand for potatoes. In comparison to industrialized nations, the country's yield is almost 1.5 times lower (Updhyay et al., 2020). 16–19 °C is the most suitable soil temperature for growing tubers.

There are many different types of soil in which potatoes can be grown, but the best soil is a well-drained loamy to sandy loam. And even on sandy soils, it grows nicely when properly fertilized. Avoid using black soils since they have unfavorable chemical and physical properties. While the optimal pH is 5.5, the range of values should be between 5.0 and 7.0. Deep, light, loose, well-drained, and capable of holding onto moisture are the ideal characteristics for soil. Sprinkler, furrow, and drip irrigation are the potato's possible methods. The formation and spread of foliar diseases may not be facilitated by drip irrigation, which is more costly than sprinkler watering, though it is becoming more effective.

In Nepal, commercial cultivation practices for potato production are increasing almost continuously in spite of a decreasing total cultivated area. Panchthar district covers an area of 2,473 hac, with a productivity of 16.93 mt/ha and a production of 41,856 mt. The total land area under potato production in Nepal is 198,788 hac, with a productivity of 3,325,231 mt and a productivity of 16.73 mt/hac (MoALD, 2020/21). Furthermore, one of the most accessible institutes in Nepal for the development of new varieties is the National Potato Research Program (NPRP). A total of sixteen potato cultivars have been produced and formally declared; eleven have been made public, and five have been registered for use in various agroecological situations in Nepal (NPRP, 2020).

Mulching is an agronomical practice that modifies the physical environment and suppresses weeds, which helps improve soil fertility and conserve the soil in advance. (Yoo-Jeong et al., 2003). Mulching has also played a played a great role in controlling irrigation issues; it includes organic (rice straw, husk, and sawdust) as well as inorganic (i.e., plastic) materials (Bharati et al., 2020). Various other agronomic practices were also used in the potato experiment. Thus, the purpose of this experiment was to compare the development and productivity of potato cultivars grown with and without plastic mulch.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at Phalgunanda rural municipality (03, Panchthar district, Province-1, Nepal. The experimental site is located at an elevation of 1852 m or 6076 feet, with a longitude of 87.8156715, a latitude of 27.2036401, a barometric pressure of 81 kPa, and a sub-tropical region. In Panchthar district, temperature variation is widely seen, with a maximum temperature of 34^{o}C and a minimum less than 9^{o}C.

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2.1.1 Climatic condition at experimental site

The figure 1 shows weather data of the research location which was recorded from the planting to harvesting of time with 10 days interval (average month). It was found that average maximun temperature of 25ºC and minimum less than 11ºC with precipitation of average 15mm.

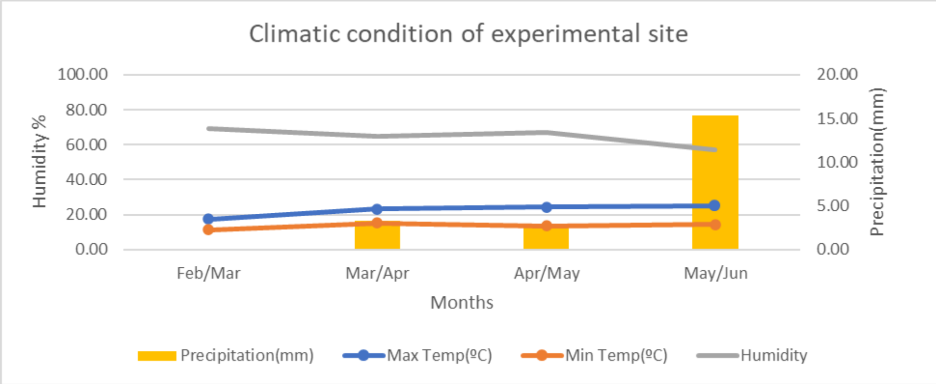

Figure 1: Weather data gathered at the experimental location in Panchthar, Nepal, every 10th day in 2022 during the potato growing season

2.2 Planting materials

The treatments consist of four potato varieties, i.e., the released variety Janakdev, the exotic variety Baijani, and two local cultivars, Betaay and Jhyalay. All these varieties were brought from different places and from locally available people. The planting was done with finely graded tubers, and large tubers were cut into medium-sized tubers. The seed rate for potatoes is 1.5–2 tons/ha (70–100 kg/ropani). The crop was sown on Feb. 14, 2022.

2.3 Experimental layout and treatment details

The experiment followed a two-factor factorial randomized complete block design (RCBD) with eight treatments, each replicated three times. The treatments involved a combination of four potato varieties, Janakdev, Baijani, Betaay, and Jhyaley and two mulch conditions (plastic mulch and no mulch). Each plot, measuring 3.0 by 1.0 square meters, contained 25 plants arranged in 5 rows with 5 plants per row, spaced 60 cm apart between rows and 20 cm within rows, with a planting depth of 5–6 cm. There was a 0.5-meter distance between treatments and a 1.0-meter distance between blocks, resulting in a total of 24 plots.

2.4 Agronomical practices

Before sowing, the field was prepared with one deep plowing using a bullock, followed by three light plowings and harrowing. The recommended fertilizer dose for potatoes was applied, consisting of FYM at 1500 kg per ropani and Urea, DAP, and MOP at 7:11:5 kg per ropani. All fertilizers were incorporated into the soil before sowing. Since mulching was used, the full nitrogen dose was applied at sowing. After preparing the field, the seeds were treated with carbendazim fungicide at 2 g/l by dipping them for 5 minutes, then drying them in the shade. Irrigation was managed according to soil type, and seasonal rainfall, with 3–4 irrigations being sufficient.

After ten days of haulm pulling, potatoes were collected. The crop was harvested with the help of a spade. After harvesting, grading was also done according to size.

2.5 Data collection

The data collection involved selecting five random plants from each plot, excluding the border plants, to measure growth and yield parameters as needed. Tubers were sorted into different sizes based on their weight using a sensitive digital scale. The cost of cultivation, gross return, net return, and benefit-cost ratio were calculated using the current prices of inputs and outputs.

2.6 Statistical analysis

The recorded data were systematically entered into MS Excel based on various observed parameters. To analyze the data, an analysis of variance (ANOVA) was performed using R-Studio (R-4.2.1). Duncan's multiple range test (DMRT) was then applied for mean separation, with a significance level set at 5%. (Gomez and Gomez, 1984)

3. Result and Discussion

3.1 Effect of varieties and mulch on growth characters

3.1.1 Days to germination and plant height

Table 1: Days to germination and plant height (cm) of potatoes in 2022 at Panchthar, Nepal, affected by cultivars and mulch conditions

Table 1: Days to germination and plant height (cm) of potatoes in 2022 at Panchthar, Nepal, affected by cultivars and mulch conditions				
Treatments	**Days to germination**	**Plant Height (cm)**		
		60DAP	**75DAP**	**90DAP**
Varieties				
Baijani	28.66c	13.69b	21.65c	63.88
Janakdev	43.15a	9.35d	19.89c	68.16
Betaay	42.49a	11.51c	27.73b	69.16
Jhyalay	34.62b	18.75a	37.56a	75.33
SEm (±)	0.64	0.31	1.30	2.59
LSD	1.94	0.94	3.96	ns
F test	***	***	***	ns
Mulch Condition				
No Mulch	36.68	11.05b	22.52b	70.66
Plastic Mulch	37.78	15.60a	30.90a	67.61
SEm (±)	0.45	0.21	0.92	1.83
LSD (0.05)	1.37	0.66	2.80	5.55
CV (%)	4.22	5.70	11.97	9.18
Grand Mean	37.23	13.32	26.71	69.13

Note: SEm: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, ns: non-significant, ***: Significant at 0.1% probability level, **: Significant at 1% probability level, *: Significant at 5% probability level, values with the same letters in the columns are not significantly different at 5% DMRT (Duncan Multiple Range Test).

The analysis of variance result reveals that mulching had no impact on days to germination, but varieties do, and there was no interaction effect among the varieties and mulching. Varieties Baijani and Jhyalay germinated earlier than Betaay and Janakdev in the location. The varieties Baijani and Jhyalay germinated at 28.66 and 34.62 days, while Betaay and Janakdev showed 42.49 and 43.15 days, respectively.

The plant height at 60 days of Jhyalay is the highest, i.e., 18.75 cm, and Janakdev shows the lowest height of 9.35 cm compared to Betaay and Baijani varieties. The plant heights of the Janakdev and Baijani variations were statistically similar at 75 days; however, they were both noticeably shorter than those of the other varieties. There was an interaction effect between the varieties and mulching at 90 days, but no significant differences were found amongst the varieties. Jhyalay had the greatest plant height value, measuring 75.33 cm. Plant morphological traits, such as height, are greatly influenced by variety because of genetic differences (Pradhan, NANDESHWAR, SARKAR, & KON AR, 2011).

3.1.2 Average number of branches, leaves and stem girth

Table 2: In Panchthar, Nepal in 2022, the average number of branches, leaves, and stem girth (cm) was affected by potato cultivars and mulch conditions

Treatments	Average number of Branches		Average number of Leaves		Stem Girth (cm)	
	60DAP	75DAP	60DAP	75DAP	60DAP	75DAP
Varieties						
Baijani	18.46^{bc}	29.00^{bc}	131.36^{b}	221.66^{b}	0.77^{a}	0.94
Janakdev	15.13^{c}	26.50^{c}	82.40^{c}	150.16^{c}	0.53^{c}	0.86
Betaay	19.83^{b}	30.33^{b}	150.43^{b}	235.50^{b}	0.74^{a}	0.93
Jhyalay	32.80^{a}	40.73^{a}	228.50^{a}	301.10^{a}	0.58^{b}	0.88
SEm (±)	1.32	1.19	12.27	13.13	0.01	0.03
LSD	4.02	3.61	37.23	39.83	0.03	ns
F test	***	***	***	***	***	ns
Mulch Condition						
No Mulch	16.76^{b}	28.23^{b}	112.71^{b}	189.78^{b}	0.56^{b}	0.80^{b}
Plastic Mulch	26.35^{a}	35.05^{a}	183.63^{a}	264.43^{a}	0.75^{a}	1.01^{a}
SEm (±)	0.93	0.84	8.68	9.28	0.007	0.02
LSD (0.05)	2.84	2.55	26.33	28.16	0.02	0.07
CV (%)	15.05	9.22	20.29	14.16	3.83	9.89
Grand Mean	21.55	31.64	148.17	227.10	0.65	0.90

Note: SEm: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, ns: non-significant, ***: Significant at 0.1% probability level, **: Significant at 1% probability level, *: Significant at 5% probability level, values with the same letters in the columns are not significantly different at 5% DMRT (Duncan Multiple Range Test).

In Jhyalay (32.80), the average number of branches was statistically higher than that of the other varieties, at 60 DAP. Jhyalay has the most branches, at 75 DAP, while Janakdev has the fewest (26.50). The quantity of aerial branches is related to the quantity of eyeballs and sprouts per eye. (Hawkes & Fransico-Ortega, 1993).

Comparing Janakdev to the other varieties, the average number of leaves was statistically lower at 60 DAP. While it was similar in Baijani and Betaay, Jhyalay had the most leaves at 75 DAP. The complicated relationship between variations' associations with leaf number and development is what causes the variation (Kirby et al., 1985).

One vegetative factor that either directly or indirectly affects yield characteristics is a plant's stem girth (Manoj Bhatta, 2020). The results of the analysis of variance showed that there was a statistically significant difference in stem girth across the various treatments, with Baijani and Betaay having the largest stem girth at 60 DAP. But there seemed to be no significant difference in stem girth at 75 DAP (Table 2).

3.2 Effect of varieties and mulch on Yield parameters

3.2.1 Tuber weight per hill (kg) and number per hill, weight per tuber and tuber weight per plot (kg/m2)

Table 3: Influenced by potato types and mulch conditions, tuber weight per hill (kg), number of tubers per hill, weight per tuber, and tuber weight per plot (kg/m^2) in Panchthar, Nepal in 2022

Treatments	Weight of tubers per hill (Kg)	Number of tubers per hill	Average weight of tubers (g)	Tubers weight per plot (Kg/m^2)
Varieties				
Baijani	0.38	16.72^{b}	45.61^{a}	4.91^{b}
Janakdev	0.55	17.60^{b}	38.04^{b}	5.71^{b}
Betaay	0.66	21.40^{b}	32.02^{c}	8.44^{a}
Jhyalay	0.61	41.05^{a}	15.36^{d}	5.83^{b}
SEm (±)	0.07	2.93	1.96	0.58
LSD	ns	8.91	5.95	1.77
F test	ns	***	***	**
Mulch Condition				
No Mulch	0.58	23.21	31.52	5.77
Plastic Mulch	0.52	25.17	33.99	6.67
SEm (±)	0.05	2.07	1.38	0.41
LSD (0.05)	ns	ns	ns	ns
CV (%)	32.56	29.73	14.67	23.03
Grand Mean	0.55	24.19	32.76	6.22

Note: SEm: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, ns: non-significant, ***: Significant at 0.1% probability level, **: Significant at 1% probability level, *: Significant at 5% probability level, values with the same letters in the columns are not significantly different at 5% DMRT (Duncan Multiple Range Test).

There was no significant difference among the varieties and mulching in weight of tuber, but the least was in Baijani and similar in Betaay and Jhyalay.

Mulching and variety had a varying effect on the number of tubers per hill (Table 3). In Jhyalay, a significantly higher number of tubers were found per hill. The number of tubers per hill was statistically similar among Baijani, Betaay, and Janakdev but significantly lower in Baijani. Similar numbers of tubers were found per hill for both plastic mulch and no mulch. The number of stems per tuber was dependent on the number of eyes, which determines the number of tubers per hill, as discussed by (Hawkes, 1990; Struik, 2007). Another study also found significantly different tuber numbers per plant among varieties (Gainju, 2018; Luitel et al., 2013)

According to Table 3, varieties but not mulch conditions had an effect on the weight per tuber. Statistically, Baijani had a higher weight per tuber than Janakdev. Jhyalay has the lowest weight per tuber as compared to other varieties. The weight per tuber is determined by the variation of tuber sizes among varieties and the number of tubers per hill.

Table 3 shows that whereas mulch condition had no effect on the tuber weight per plot, variety affected, the tuber weight per plot was statistically similar and comparable in Baijani, Janakdev, and Jhyalay, and tuber weight per plot seems to be the lowest, whereas Betaay has the highest tuber weight per plot (8.44).

3.2.2 Effect of varieties and mulch on tuber distribution and yield

Table 4: In Panchthar, Nepal in 2022, the distribution of tubers by number and yield was determined by the cultivars and mulch conditions of potatoes.

Treatments	Total number of tubers <25g	Total number of tubers (25–50g)	Total number of tubers >50g	Total yield (T/hac)
Varieties				
Baijani	12.95[b]	3.11[c]	2.77	16.37[b]
Janakdev	15.79[b]	4.02[bc]	4.27	19.03[b]
Betaay	14.76[b]	5.28[b]	5.52	28.13[a]
Jhyalay	33.30[a]	7.87[a]	4.16	19.45[b]
SEm (±)	2.23	0.46	0.73	1.95
LSD	6.79	1.39	ns	5.91
F test	***	***	ns	**
Mulch Condition				
No Mulch	18.34	5.11	4.54	19.25
Plastic Mulch	20.06	5.03	3.82	22.24
SEm (±)	1.58	0.32	0.51	1.37
LSD (0.05)	ns	ns	ns	ns
CV (%)	28.55	22.24	42.78	23.03
Grand Mean	19.20	5.07	4.18	20.75

Note: SEm: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, ns: non-significant, ***: Significant at 0.1% probability level, **: Significant at 1% probability level, *: Significant at 5% probability level, values with the same letters in the columns are not significantly different at 5% DMRT (Duncan Multiple Range Test).

Based on the characteristics of the different varieties, the distribution of tubers by hill determines their suitability for a certain purpose. (Shrestha et al., 2020). Table 4 shows the tuber distribution by number per hill of the various varieties after grading, with and without mulch. Variety, but not mulch condition, had a significant effect on the distribution of numbers. Jhyalay (33.30) reported a significantly larger number of small-sized tubers (<25 g), and it seems that other varieties were similar. Depending on the varietal characteristics, the number and weight of tubers per hill influence their suitability for a particular purpose in Okhaldhunga, Nepal (Ghimire et al., 2020).

Table 4 shows that the total number of tubers (>50 g) was not significant among the varieties and mulch conditions.

The potato varieties significantly impacted tuber yield, as shown in Table 4. The highest yield was recorded for Betaay (28.13 t ha-1), followed by Janakdev and Jhyalay, which had similar yields. Baijani had the lowest yield among the varieties (16.37 t ha-1). The analysis of variance indicated that there was no significant difference between the mulching conditions.

3.2.3 Distribution of tubers by weight and number according to size (Grading/ Sorting)

The records were kept based on tuber weight, measured with a balance. Tubers were categorized into different sizes: undersized (<1 cm, unmarketable), small (1–2.5 cm, marketable), medium (2.5–3.5 cm, marketable), and large (>3.5 cm, marketable), determined visually (as shown in Figure 2). And tubers in each size group were counted and weighed.

Figure 2: Potatoes were physically graded into several categories according to size

3.3 Effect of variety and mulch on morphological characteristics of tubers

Table 5 presents the tuber shape, eye depth, tuber color, and flesh color for the potato varieties used. The four varieties showed differences in tuber shape, eye depth, tuber color, and flesh color. Two varieties had red tubers, one had dark purple, and one had white. Eye depth varied, with two varieties having deep eyes, two having shallow eyes, and two having medium eye depth.

Table 5: Morphological characteristics of tubers as influenced by varieties and mulch conditions in potato in 2022 at Panchthar, Nepal

S. N	Varieties	Shape of tubers	Eye depths	Tuber colors	Tuber flesh colors
1	Baijani	Round	Medium	Dark purple	Purple
2	Janakdev	Oblong	Shallow	Red	Pale yellow
3	Betaay	Round	Deep	Red	White
4	Jhyalay	Oblong	Medium	White	White

Figure 3: Baijani

Figure 4: Janakdev

Figure 5: Betaay

Figure 6: Jhyalay

3.4 Effect of varieties and mulch on Economic analysis

The data for cost of production, net return, gross return, and B:C ratio are shown in Table 6. Production costs included the general cost of cultivation and treatment-wise variable costs. While gross return was not influenced by varieties or mulching, it was found to be highest in Betaay, followed by Baijani, and the lowest gross return was found in Janakdev**.** Moreover, the B:C ratio was found to be significantly different with varieties and mulch conditions. B:C ratio was observed in highest in Betaay and lowest B:C ratio was found in Baijani and similar with Janakdev. However, the B:C ratio in no mulch was observed to nearly double with the mulch condition.

Table 6: The impact of cultivars and mulch conditions on economic analysis potatoes in Panchthar, Nepal in 2022

Treatments	Total cost of Cultivation (NRs. ha^{-1})	Gross return (NRs. ha^{-1})	Net Return (NRs.ha^{-1})	B:C ratio
Varieties				
Baijani	498715^{a}	1023645.8	524930.8^{bc}	2.11^{c}
Janakdev	398715^{b}	713687.5	314972.5^{c}	2.35^{c}
Betaay	238715^{d}	1055000.0	816285.0^{a}	4.93^{a}
Jhyalay	298715^{c}	972833.3	674118.3^{ab}	3.53^{b}
SEm (±)		89660.47	89660.47	0.34
LSD (0.05)			271956.9	1.04
F test	***		**	***
Mulch Condition				
No Mulch	240000^{b}	876010.4	636010.4	4.14^{a}
Plastic Mulch	477430^{a}	1006572.9	529142.9	2.32^{b}
SEm (±)		63399.53	63399.53	0.24
LSD (0.05)				0.74
CV (%)		23.33	37.69	26.23
Grand Mean	358715	941291.7	582576.7	3.23

Note: SEm: Standard error of mean, LSD: Least significant difference, CV: Coefficient of variation, ns: non-significant, ***: Significant at 0.1% probability level, **: Significant at 1% probability level, *: Significant at 5% probability level, values with the same letters in the columns are not significantly different at 5% DMRT (Duncan Multiple Range Test).

4. Conclusion

The study concludes that Jhyalay and plastic mulch resulted in better plant growth due to improved aeration, optimal soil temperature, and enhanced soil water retention. The highest tuber yield was achieved with the Betaay variety, followed by Janakdev and Jhyalay, primarily due to the higher yield per plot. Betaay and Jhyalay were identified as the most suitable potato varieties for the Panchthar-like climate, contributing the highest yield, gross return, net return, and benefit-cost (B:C) ratio. However, the output from plastic mulch was higher, but it also had a statistically poorer net return and B:C ratio than when there was no mulch. The expensive expenses of producing plastic mulch could be the cause of this.

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