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Performance of different potato varieties under plastic mulching conditions at Dailekh, Nepal

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ABSTRACT

Mulching helps to preserve soil fertility by preventing moisture loss, maintaining soil temperature, limiting weed growth, promoting microbial growth, and minimizing soil erosion. An experimental study was conducted to assess the effect of plastic mulching and control conditions (as main factors) on yield attributes of five potato varieties, namely Khumal Seto-1, Desiree, Cardinal, Kufri-Jyoti, and C-88 (as sub-factors), in Dailekh, Nepal. A Split-plot design was employed comprising altogether ten treatments with three replications each. R-Studio software was used to analyze the data and attribute the responses to growth and yield parameters. The Duncan's Multiple Range Test (DMRT) was used to differentiate the treatment means at 5% level of significance. Mulching treatment was found to be significantly more effective than no mulch for all the vegetative growth attributes. Compared to no mulch, the use of plastic mulch produced the greatest plant height (38.66 cm) at 75 DAS, highest number of marketable tubers (11.64), and the total number of tubers per hill (13.04), marketable tuber yield (3.93 kg/m2), and a significantly higher total tuber yield of 25.48 t/ha. Similarly, total tuber yield was found to be highest for Khumal Seto-1 (25.32 t/ha) and least for Kufri-Jyoti (22.38 t/ha). The benefit-cost analysis was found to be significant for the mulch condition and Khumal Seto-1, with promising ratios of 3.28 and 3.48, respectively. Thus, Khumal Seto-1 under plastic mulching may be used for better productivity of potatoes in Dailekh, and moreover, other readily available and accessible mulch options, including organic mulch-materials, can be utilized.

Keywords: Cardinal, Desiree, Khumal Seto-1, Kufri-Jyoti, marketable tuber yield, yield parameters

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1 Introduction

The potato (*Solanum tuberosum* L.) ranks as the fourth most important crop in the world after cereal crops such as wheat, rice, and maize. Among the major potato-producing countries in Asia, Nepal currently ranks ninth on the list (Ghimire et al., 2021). Potatoes are considered an important cash crop to address food insecurity and alleviate poverty among impoverished farmers in developing countries like Nepal (Timsina et al., 2013). It is a major staple food in the highlands and has a significant influence on the general diet of Nepalese (Gairhe et al., 2017). The mid-hills of Nepal are the main domain of potato production with 41.5% area coverage followed by plains (38.5%) and highlands (20%). The crop is grown across broad agro-ecological conditions from 100 m to 4000 m altitude (Dahal and Rijal, 2019). In Nepal, Potato covers an area of 198,788 ha with an average production of 3,325,231 tons and a productivity of 16.73 t/ha respectively (MoALD, 2020). In Dailekh, 33,450 metric tons of potatoes are produced annually in an area of 1,924 ha (MoALD, 2020). Many essential nutrients for human health like carbohydrates, protein-containing dietary fiber, vitamin C, vitamin B6, potassium, magnesium, iron, carotenoids, and phenolic acids, etc. are found in ample amounts in potato (Beals, 2018;

Navarre et al., 2019).

The soil, climatic conditions, and diverse production strategies, all influence potato growth and yield. Surface mulch is an important factor of soil protection technology that affects the soil temperatures and water potential of the soil (Dvořák et al., 2012). Mulching is one of the major intercultural operations for potatoes, contributing minimal soil disturbance and nutrient loss along with efficient water use (Ahmed et al., 2017a). Among many mulching materials, plastic mulches have been found to have a very positive impact on soil in arid areas, enhancing fertility and yield, preventing erosion, conserving soil moisture, and enhancing yield (Moreno and Moreno, 2008), as well as weed control (Hidayat et al., 2013). According to Zahed et al. (2021), mulching is an important intercultural operation in potatoes for temperature maintenance and disease control. Mulching has a very positive effect on emergence (Mahmood et al., 2002). Black plastic mulching advanced the germination and sprouting of seed tubers by 7–10 days compared with the unmulched plots (Sekhon et al., 2020). The black plastic mulch significantly increased the rate of emergence, all other studied growth parameters, yield components, and quality parameters (Bhatta et al., 2020). The increased soil temperature caused by different plastic mulches resulted in faster germination, flowering, and physiological maturity under mulch conditions. Mulching can affect the external quality of tubers (scab of tubers, mechanical damages, greening of potato tubers) and inner quality (chemical composition) as well (Dvořák et al., 2012). Black plastic mulch is the most available and most used of others; it absorbs UV (ultraviolet), visible, and infrared wavelengths of solar radiation released from the sun and significantly impacts soil heat (Amare and Desta, 2021). Colored black plastic mulches have been shown in various studies to improve soil temperature, growth, yield, and photosynthetic response in potato plants (Ibarra-Jiménez et al., 2011).

Since it is impossible to increase the area under cultivation, the advances in scientific technology of potato production can increase its production. According to (Zhang et al., 2022), plastic mulching has a significant economic benefit by allowing for re-use in crop land, which reduces costs as well as vulnerability to the environment and ultimately leads to increased revenue. This method of plastic mulching leads to environmentally friendly, efficient, and sustainable agriculture. Therefore, use of appropriate type of mulching can be one of the best alternative solutions to increase the production and productivity of potatoes to meet the demand of the increasing population as it has multiple benefits in terms of yield and input efficiency. Thus, this research aims to assess the tuber yield and yield attributes of different varieties of Potato under plastic mulching conditions, to encourage farmers for adopting the best commercially suitable variety and increase domestic production and productivity.

2 Materials and Methods

2.1 Experimental site

The experiment was conducted in the farmer's field selected within the command area of Potato Block, Dailekh of Karnali province, during the spring of 2022 (from 3rd week of February to June).

2.2 Physico-chemical characteristics of the experimental soil

To analyze the initial physico-chemical properties of the soil in the experimental area, soil samples were collected randomly at 0 to 20 cm depth from the surface at the four corners and the center of each of the experimental plots. Additionally, for the purpose of determining the amount of organic matter, the sub-samples were combined, air-dried in the shade, crushed, and sieved through a 2 mm sieve and a 0.5 mm sieve. Following collection, the samples were placed in plastic containers and delivered to the Soil Testing Laboratory, Birendranagar, Surkhet, for the test. The results of the test conducted showed the soil texture of the research plot to be loam-type. The pH of the soil was found to be acidic (5.6) in nature. The total nitrogen content of the soil was found to be high (0.3%), while available phosphorus (51.53 kg/ha) was medium and available potassium (410.91 kg/ha) was high. Further, the organic matter content of the soil was found to be high (6.1%). The details of the methods and methodology used for examining the physico-chemical properties of the soil are depicted in the Table 1.

2.3 Agro-meteorological condition

The experimental site lies in the subtropical humid climate belt of Nepal. The meteorological data for the cropping season of 2022 was recorded from NASA power. As per the observation of meteorological parameters, the average maximum temperature (Tmax) observed was 21.25 °C, whereas the average minimum temperature (Tmin) observed was 10.94 °C. The average relative humidity during the study period was reported to be 59.21%. The monthly average rainfall of 1.18 mm/day was received during the entire period of experimentation.

2.4 Experimental details and design

The experiment was set up in a split-plot design with ten treatments and three replications. The treatments

Table 1. Methods used to determine the chemical and physical properties of soil of the experimental site at Dailekh, Nepal in 2022

Chemical properties	Content	Rating	Methods
Soil pH	5.6	Acidic	Beckman Glass Electrode (Estefab, 2013)
Soil organic matter (%)	6.1	High	Walkley and Black (Estefab, 2013)
Total nitrogen (%)	0.3	High	Micro Kjeldahl distillation (Estefab, 2013)
Available phosphorus (kg/ha)	51.53	Medium	Modified Olsen's method ((Estefab, 2013)
Available potassium (kg/ha)	410.91	High	Ammonium acetate method (Estefab, 2013)

consisted of the main factor: mulch and control (non-mulch) with sub-factors of five potato varieties: Khumal Seto-1, Desiree, Cardinal, Kufri-Jyoti, and C-88 combined to form ten treatments. The research was conducted on a total plot size of 108 m^2 with 30 plots, each of size 3 m $\times$ 1.2 m comprising a total of 25 plants in five rows, each row with five plants at the spacing of 60 cm $\times$ 20 cm (row-row and plant-plant spacing).

2.5 Cultivation practice

The field was heavily plowed and tilled. Final tillage was done one week before the crop plantation. The weeds and stubble were removed from the field, then it was divided into different plots according to the experimental design. Seed tubers were treated with Mancozeb at the rate of 3 g/L against late blight disease one day before sowing. Farm Yard Manure (FYM) at the rate of 30 tons/ha and Urea (100 kg/ha), DAP (100 kg/ha), and MOP (60 kg/ha) as the source of NPK were incorporated into the field before sowing. A full dose of nitrogen was given as the basal dose at the time of sowing as mulches would hinder later application on the field. Healthy, well-sprouted, and finely graded medium-sized potato tubers weighing about 25 to 30 grams were selected. Potato seed tubers were sown at a spacing of 60 cm $\times$ 20 cm (row-row and plant-plant spacing). There were five rows in each plot, with five plants in each row. Thus, each plot had 25 plants. The tubers were sown in furrows. Irrigation for the crop was given in-furrow when required. Haulms were destroyed 14 days before the harvest to reduce damage at harvest. Harvesting was done after 10–15 days of haulm pulling. Digging was done with the help of spades (commonly called "Khurpi") in small fields. After harvesting, tubers were graded according to their sizes.

2.6 Observations and data collection

Five plants were chosen, inclusive of various intra-plot variations. The sample plants were selected, and the border plants were excluded. The required parameters were observed in the sample plants at an interval of 15 days.

The gross income, net benefit, and benefit-cost ratio were calculated for five different potato varieties. FYM and chemical fertilizers were calculated and analyzed based on input and output prices during the experimental period. The following calculations were done for economic analysis:
Gross income = Yield (kg/ha) x Price (per kg)
Total cost = Cost of (inputs + Labor + machines) used
Net return = Gross income - Total cost
B:C ratio = (Gross income)/(Total Cost)

2.7 Data analysis and interpretation

Experimental data were tabulated using Microsoft-Excel and analyzed using R studio with R stat Software of 4th edition. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance. Analysis of variance (ANOVA) was used to test differences among the two factors under study.

3 Results and Discussion

3.1 Plant height

The data were collected at 45 days after sowing (DAS), 60 DAS, and 75 DAS respectively. The influence of varieties and mulching on the height of potato is illustrated in Table 2. The plant height of the potato was found to be significantly influenced by mulching at all growth stages. Compared to the control (non-mulch condition), the tallest plant height was recorded in mulch condition at all growth stages. During all stages (45, 60, and 75 days after sowing), the highest plant height was observed in the mulch condition (20.05, 37.68, and 38.66 cm) as compared to the control condition (16.32, 31.21, and 33.12 cm), respectively. The increased plant height under mulching conditions might be due to mulching, increasing the availability of soil moisture and resulting in ideal soil temperatures (Ahmed et al., 2017b). The superiority of plastic mulch in promoting the height of plants might be attributed to early emergence. Plastic mulch provides better availability of soil moisture and optimum soil temperature which contribute to increased plant height (Bharati et al., 2020). The higher soil

Table 2. Influence of potato varieties and mulching on the plant height of potato at Dailekh, Nepal in 2022

Treatment	Plant height (45 DAS)	Plant height (60 DAS)	Plant height (75 DAS)
Mulching			
Mulch	20.053a	37.68a	38.66a
Non-Mulch	16.32b	31.21b	33.12b
SEM	1.8648	3.24	2.77
LSD (0.05)	2.64	2.8	0.801
CV (%)	9.30	5.20	1.40
F-test	*	**	**
Varieties			
Khumal Seto-1	19.9a	37.23a	38.59a
Desiree	18.56b	31.93e	33.91d
Cardinal	17.57c	34.28c	35.85c
Kufri- Jyoti	16.18d	33.02d	33.99d
C-88	18.73b	35.78b	37.08b
SEM	0.62365	0.94	0.901
LSD (0.05)	0.40593	0.72	1.065
CV (%)	1.80	1.70	2.40
F-test	***	***	***
Interaction			
F-test	ns	*	ns
Grand Mean	18.19	34.45	35.89

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

temperature under plastic mulches leads to an active metabolism in the plants and enhancement of growth.

Regarding potato varieties, significant results were obtained in between the factors at 45, 60, and 75 DAS. At 45 days after sowing, plant height was found to be significantly higher in Khumal Seto-1 (19.9 cm) followed by C-88 (18.73 cm), which was found to be statistically similar to Desiree (18.56 cm). The plant height was found to be the least for Kufri-Jyoti (16.18 cm), which was statistically different from Cardinal (17.57 cm). At 60 days after sowing, the tallest plant height was recorded in Khumal Seto-1 (37.23 cm), followed by C88 (35.78 cm) and Desiree (31.93 cm). The plant height was found least for Kufri-Jyoti (33.02 cm), which was statistically different from Cardinal (34.28 cm). At 75 DAS, the tallest plant height was recorded in Khumal Seto-1 (38.59 cm), followed by C-88 (37.08 cm), Cardinal (35.85 cm), and least for Kufri-Jyoti (33.99 cm), which was statistically similar to the plant height of Desiree (33.91 cm). This variation in plant height is likely due to food reserves for the initial growth of seed tuber and varietal characteristics, as well as interactions of planting material and the environment (Haque, 2007). The variation might be most probably due to plant genetics and the inherent characteristics of different varieties. Also, these differences in plant height among the varieties might be due to plant genetics and the quality of the plant material as reported by Eaton et al. (2017).

Table 3. Interaction effect of varieties and mulching on the height of Potato at 60DAS, Dailekh, Nepal in 2022

Varieties	Mulch	Control
Khumal Seto-1	39.85a	34.60d
Desiree	35.30d	28.56g
Cardinal	38.11b	30.45f
Kufri-Jyoti	36.34c	29.69f
C-88	38.81b	32.74e
LSD (0.05)	1.018	
CV (%)	1.70	
SEm (±)	1.26	

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

The interaction effect of mulching and potato varieties on plant height was significant only at 60 DAS (Table 3). Maximum plant height (39.85 cm) was obtained from the treatment M1V1 (mulch + Khumal Seto-1), which was followed by the treatment M1V5 (mulch + C-88). The other treatment produced significantly lower plant height.

Table 4. The Number of stems per tuber and number of leaves per stem of Potato as influenced by varieties and mulching of Potato at Dailekh, Nepal in 2022

Treatment	No. of stems/tuber		No. of leaves/stem		Stem diameter (mm)		No. of branches/stem	
	45DAS	60DAS	45DAS	60DAS	60DAS	75DAS	60DAS	75DAS
Mulching								
Mulch	5.053a	6.37a	8.94a	9.55a	6.7a	9.33	30.14a	49.743a
Control	4.06b	5.01b	7.93b	8.61b	5.86b	8.26	25.97b	43.62b
SEM	0.497	0.68	1.8648	0.47	0.42	0.54	2.085	3.062
LSD (0.05)	0.42	1.34	1.0746	0.88	0.179	1.81	0.47	1.32
CV (%)	5.90	12.20	8.10	6.20	1.80	8.60	5.80	1.80
F-test	**	*	*	*	**	ns	*	**
Varieties								
Khumal Seto-1	4.38d	5.29d	8.21b	8.88d	6.20d	8.68d	29.015b	48.48b
Desiree	4.73b	6.07b	8.83a	9.43a	6.5a	9.09a	30.79a	50.47a
Cardinal	4.583c	5.70c	8.70a	9.26b	6.40b	8.91b	27.78c	46.38c
Kufri- Jyoti	4.90a	6.42a	8.55a	9.12c	6.27c	8.79c	26.948d	44.71d
C-88	4.183e	4.03e	7.895b	8.73e	6.07e	8.51e	25.748e	43.368e
SEM	0.126	0.251	0.624	0.127	0.08	0.11	0.866	1.28
LSD (0.05)	0.13	0.197	0.32	0.115	0.027	0.105	0.47	1.16
CV (%)	2.40	2.90	3.10	1.00	0.40	1	1.40	2
F-test	***	***	***	***	***	***	***	***
Interaction								
F-test	ns	ns	ns	ns	ns	ns	ns	ns

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

3.2 Number of stems per tuber

The number of stems per hill, being a yield-attributing character, contributes to the total yield of potato. The number of stems per tuber of potato was significantly influenced by mulching at all growth stages. At 45 and 60 days after sowing, the highest number of stems per tuber was observed with a mulch condition (5.05 and 6.37) as compared to control conditions (4.06 and 5.01) (Table 4). Such response was mainly due to biological, physicochemical, and other activities of soil, including temperature maintenance, nutrient availability, and microbial activity in mulch conditions (Bharati et al., 2020).

Regarding potato varieties, significant results were obtained at 45 and 60 days after sowing. At 45 days after sowing, the number of stems per tuber was recorded higher in Kufri-Jyoti (4.9), followed by Desiree (4.73 cm) and Cardinal (4.583). The number of stems per tuber was recorded as least for C-88 (4.183) which was statistically different from Khumal Seto-1 (4.38). At 60 days after sowing, the number of stems per tuber was recorded as highest in Kufri-Jyoti (6.42), followed by Desiree (6.07), Cardinal (5.7), and least for C-88 (4.03) which was statistically different from Khumal Seto-1 (5.29). Generally, The number of main stems per hill might depend on the quality of the tuber used and the number of buds present on the tuber. The variation in stem number is genotype-dependent (Luitel et al., 2016). This variation in the number of stems per tuber in potato varieties might be due to varietal characteristics (Lalitha et al., 2010).

3.3 Number of leaves per stem

Leaf number is one of the major yield-attributing characters of potato (Table 4). The number of leaves per stem of potato was significantly influenced by mulching at all growth stages. At 45 days after sowing, the highest number of leaves per stem (30.14) was observed in mulch condition. Regarding potato varieties, significant results were obtained at 45 and 60 days after sowing. At 45 days after sowing, the number of leaves per stem was recorded higher in Desiree (30.79), followed by Khumal Seto-1 (29.015) and Cardinal (27.78). The number of leaves per stem was found to be the least for C-88 (25.748) which was statistically different from Kufri-Jyoti (26.948). At 60 days after sowing, the number of leaves per stem was recorded higher in Desiree (50.47), followed by Khumal Seto-1 (48.48), Cardinal (46.38), and least in C-88 (43.368) which was statistically different from Kufri-Jyoti (44.71).

This variation in the number of leaves per stem in potato varieties might be due to many factors, including genotype (varietal characteristics) and environment. Similar findings were reported by Banjade et al. (2019) and Shrestha et al. (2020) during their varietal trial. The result was as expected as genotypes normally differ in growth pattern, stem height, and number of leaves per plant (Tessema et al., 2020).

3.4 Stem diameter

The stem diameter of a plant is one of the vegetative parameters that contribute to yield parameters directly or indirectly (Table 4). At 60 and 75 days after sowing, the highest stem diameter was recorded at a mulch condition (8.94 and 9.55 mm) as compared to control conditions (7.93 and 8.61), respectively. Plastic mulching creates a favourable environment for the vigorous growth of root and shoot of the plant. Also, Higher stem diameter of tomato was reported in polyethylene mulches in an experiment led by Arin and Ankara (2001) and Bhandari and Bhandari (2021).

Regarding potato varieties, significant results were obtained. At 60 days after sowing, the stem diameter was recorded higher in Desiree (8.83), which was statistically similar to Cardinal (8.70), and Kufri-Jyoti (8.55). The stem diameter was found to be the least for C-88 (7.895) which was statistically similar to Khumal Seto-1 (8.21). At 75 days after sowing, the stem diameter was recorded higher in Desiree (9.43), which was statistically similar to Cardinal (9.26) and Kufri-Jyoti (9.12). The stem diameter was found to be the least for C-88 (8.73) which was statistically similar to Khumal Seto-1 (8.88). This variation in stem diameter among potato varieties might be due to varietal traits.

3.5 Number of branches per stem

The number of branches per stem of potato was significantly influenced by mulching at 60 days after sowing (Table 4). The highest number of branches per stem was recorded at a mulch condition (6.7) as compared to the control condition (5.86). According to Agrawal et al. (2016), increased rate of photosynthesis and maximum photosynthate supply to branches along with the change in indigenous auxin for apical dominance were the probable cause for the increase in branch number. Also, the increased in number of branches might be due to nutrient availability, a favorable temperature range, and microbial activity in mulch conditions promoting the optimum foliage growth and the vegetative cover (Bharati et al., 2020).

Regarding potato varieties, significant results were obtained at 60 and 75 days after sowing. At 60 days after sowing, the number of branches per stem was recorded higher in Desiree (6.5), followed by Cardinal (6.4), and Kufri-Jyoti (6.27). The number of branches per stem was found to be the least for C-88 (6.07) which was found to be statistically different from Khumal Seto-1 (6.2). At 75 days after sowing, the number of branches per stem was recorded higher in Desiree (9.09), followed by Cardinal (8.91), and Kufri-Jyoti (8.79). The number of branches per stem was found to be the least for C-88 (8.51) which was statistically different from Khumal Seto-1 (8.68). This variation in the number of branches per stem in potato varieties might be due to varietal characteristics. The variations in number of branches per plant among the different potato cultivars might be due to different genetic make-up and better adaptability to prevailing environment conditions. Similar results were reported by Jatav et al. (2017) and Preetham et al. (2018).

3.6 Canopy diameter

Canopy diameter is another crucial parameter on which tuber yield depends to a certain extent. The data were collected at 45 DAS, 60 DAS, and 75 DAS. The influence of varieties and mulching on the Canopy diameter of Potato is illustrated in Table 5. The canopy diameter of the Potato was significantly influenced by mulching at 60 and 75 days after sowing. At 60 and 75 days after sowing, the highest canopy diameter was observed with a mulch condition (35.28 and 53.26 cm) as compared to control conditions (31.32 and 47.52cm). These results were also in accordance with the findings of Zhao et al. (2012), which reported that higher soil temperatures under plastic mulch led to more active plant metabolism, increased nutrient uptake, and improved growth parameters such as canopy diameter.

Regarding potato varieties, significant results were obtained at 45, 60, and 75 days after sowing. At 45 days after sowing, the canopy diameter was recorded higher in Desiree (21.91 cm), followed by Khumal Seto-1 (21.02 cm) and Cardinal (20.35 cm). The canopy diameter was found to be the least for C-88(18.72 cm) which was statistically different from Kufri-Jyoti (19.56 cm). At 60 days after sowing, the canopy diameter was recorded higher in Desiree (35.21 cm), followed by Khumal Seto-1 (34.24 cm), and Cardinal (33.33 cm). The canopy diameter was found to be the least for C-88(31.39 cm) which was statistically different from Kufri-Jyoti (32.32 cm). At 75 days after sowing, the canopy diameter was recorded higher in Desiree (52.27 cm), followed by Khumal Seto-1(51.43 cm) and Cardinal (50.28 cm). The canopy diameter was found to be the least for C-88 (48.51 cm) which was statistically different from Kufri-Jyoti (49.45 cm). The rate of energy and material exchange between plant canopies and the atmosphere is determined by the leaf area index (LAI) of the plants (Thapa, 2022; Vose et al., 1994). Differences in canopy diameter between varieties might be influenced by

Table 5. The canopy diameter as influenced by varieties and mulching of Potato at Dailekh, Nepal in 2022

Treatment	Canopy Diameter		
	45 DAS	60 DAS	75 DAS
Mulching			
Mulch	21.45	35.28a	53.26a
Control	19.17	31.32b	47.52b
SEM	0.91	1.98	2.87
LSD (0.05)	0.433	2.37	1.62
CV (%)	1.40%	4.50%	2%
F-test	ns	*	**
Varieties			
Khumal Seto-1	21.02b	34.24b	51.43b
Desiree	21.91a	35.21a	52.27a
Cardinal	20.35c	33.33c	50.28c
Kufri- Jyoti	19.56d	32.32d	49.45d
C-88	18.72e	31.39e	48.51e
SEM	0.59	0.67	0.67
LSD (0.05)	0.37	0.39	0.08
CV (%)	1.50%	1%	0.50%
F-test	***	***	***
Interaction			
F-test	ns	ns	ns

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

both genetic and environmental factors. This results were inline with the findings of (Thapa, 2022).

3.7 Number of tubers

The marketable tuber number per hill, unmarketable tuber number per hill, and the total number of tubers per hill were found non-significant in the plastic mulching compared to the control conditions (Table 6). The number of Marketable tubers per hill (>25 g) was found to be significantly higher for Desiree (11.93), followed by Khumal Seto-1 (11.35), which is statistically at par with C-88 (11.07). The number of Marketable tubers per hill (>25 g) was found to be significantly lower for Kufri-Jyoti (10.71), which was statistically at par with cardinal (10.93). The number of unmarketable tubers per hill (<25 g) was found to be significantly higher for Kufri-Jyoti (1.9), followed by Cardinal (1.67) and Desiree (1.53). The number of unmarketable tubers per hill (<25 g) was found to be the least for C-88 (1.2) which was statistically different from Khumal Seto-1 (1.35). The total number of tubers per hill was found to be significantly higher for Desiree (13.46), followed by Khumal Seto-1 (12.7), which is statistically similar to Kufri-Jyoti (12.62) and Cardinal (12.6). The total number of tubers per hill was found to be the least for C-88 (12.27). Luitel et al. (2016) and Gainju et al. (2018) had also found different numbers of tubers per plant for the varieties in their research.

3.8 Tuber yield

The marketable tuber yield and total tuber yield were found to be significantly higher under mulched condition (3.93 kg/m^2 and 25.48 t/ha) as compared to the control condition (3.36 kg/m^2 and 22.17 t/ha), respectively (Table 6). The Unmarketable tuber yield was found to be significantly higher under the control condition (0.07 kg/m^2) as compared to the mulch condition (0.0292 kg/m^2). This was likely because mulching protects soil from water erosion and thus hinders weed growth, debilitates soil and water loss, and brings down contention with weeds for water and nutrients (Wang et al., 2011). In the presence of plastic mulch, tuber yield appeared to increase with the increasing irrigation frequency, although the difference was not statistically significant (Wang et al., 2011). The high number of medium and large-sized tubers in perforated black mulch, as observed in this study, may be due to the availability of moisture at optimal temperatures in the plant root zone and proper aeration (Kader et al., 2017). The findings were also similar to Ghimire et al. (2021) which illustrated the

Table 6. Yield parameters influenced by varieties and mulching of potato at Dailekh, Nepal in 2022

Treatment	NMT	NUT	TNT	MTY (kg/m^2)	UTY (kg/m^2)	TTY (t/ha)
Mulching						
Mulch	11.64	1.4	13.04	3.93a	0.0292b	25.48a
Control	10.76	1.66	12.42	3.36b	0.070a	22.17b
SEM	0.44	0.13	0.31	0.29	0.0204	1.7
LSD (0.05)	2.017	0.4735	2.017	0.1886	0.0041	2.564
CV (%)	8.80	19.70	10.10	3.30	5.30	6.90
F-test	ns	ns	ns	**	***	*
Varieties						
Khumal Seto-1	11.35b	1.35d	12.7b	4.183a	0.0367e	25.32a
Desiree	11.93a	1.53c	13.46a	4.055a	0.044d	24.395b
Cardinal	10.93cd	1.67b	12.6b	3.23c	0.055b	23.25d
Kufri- Jyoti	10.71d	1.9a	12.62b	2.958d	0.063a	22.38e
C-88	11.07bc	1.2e	12.27c	3.806b	0.049c	23.768c
SEM	0.21	0.12	0.198	0.24	0.0046	0.51
LSD (0.05)	0.31	0.095	0.32	0.1847	0.00242	0.4169
CV (%)	2.30	5	2	4.10	4	1.40
F-test	***	***	***	***	***	***
Interaction						
F-test	ns	ns	ns	*	ns	**

NMT: number of marketable (≥25 g) tubers/m^2, NUT: number of unmarketable (<25 g) tubers/m^2, TNT: number of total tubers/m^2, MTY: marketable tuber yield, UTY: unmarketable tuber yield, TTY: total tuber yield; Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS = Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of variance

role of mulching in increasing the temperature, accelerating root growth, and maximizing the consumption of phosphorus in the soil, and thus increasing the yields. In the case of varieties, the marketable tubers yield (kg/m^2) was found to be significantly higher for Khumal Seto-1 (4.183 kg/m^2), which was statistically similar to Desiree (4.055 kg/m^2), followed by C-88 (3.806 kg/m^2). The marketable tubers yield (kg/m^2) was found least for Kufri-Jyoti (2.958 kg/m^2), which was statistically different from Cardinal (3.23 kg/m^2).

The unmarketable tubers yield (kg/m^2) was found to be significantly higher for Kufri-Jyoti (0.063 kg/m^2), followed by Cardinal (0.055 kg/m^2) and C-88 (0.049 kg/m^2). The unmarketable tubers yield (kg/m^2) was found least for Khumal Seto-1(0.0367 kg/m^2), which was statistically different from Desiree (0.044 kg/m^2). The total tubers yield (t/ha) was found to be significantly higher for Khumal Seto-1 (25.32 t/ha), followed by Desiree (24.395 t/ha) and C-88 (23.768 t/ha). The total tubers yield (t/ha) was found least for Kufri-Jyoti (22.38 t/ha), which was statistically different from Cardinal (23.25 t/ha). Differences in yield could be attributed to differences in growth character, where the genetic makeup was responsible, along with variation in nutrient usage among varieties and the climate (Zelelew and Ghebreslassie, 2015). Additionally, according on their genetic makeup, different cultivars had varying production potential. Based on the environment's adaptability, different cultivars produced different amount of yield (Shrestha et al., 2020). The interaction was found significant for the marketable tuber yield and total tuber yield.

The interaction effect of mulching and potato varieties on marketable tuber yield was found significant (Table 7). The marketable tuber yield (4.53 kg/m^2) was produced by the treatment M1V1 (mulching + Khumal Seto-1), which was statistically at par with the treatment M1V2 (mulching + Desiree). The other treatment produced a significantly lower marketable tuber yield. The interaction effect of mulching and potato varieties on total tuber yield was significant. The total tuber yield (4.53 kg/m^2) was produced by the treatment M1V1 (mulching + Khumal Seto-1), which was statistically at par with the treatment M1V2 (mulching + Desiree). The other treatment produced a significantly lower marketable tuber yield.

3.9 Tuber grades

The number of big-sized potato tubers was significantly influenced by mulching (2.68) compared to the control condition (2.087) (Table 8). Regarding potato varieties, significant results were obtained for

Table 7. Interaction effect of varieties and mulching on the marketable tuber yield (kg/m2) and total tuber yield (ton/ha) of Potato at Dailekh, Nepal in 2022

Varieties	Marketable tuber yield (kg/m2)		Total tuber yield (ton/ha)	
	Mulch	Control	Mulch	Control
Khumal Seto-1	4.53a	3.84c	27.35a	23.29e
Desiree	4.41ab	3.70c	26.29b	22.50f
Cardinal	3.37d	3.08e	24.64d	21.86g
Kufri-Jyoti	3.15de	2.77f	23.71e	21.057h
C-88	4.20b	3.41d	25.42c	22.12fg
LSD (0.05)	0.261		0.5895	
CV (%)	4.10		1.40	
SEM (±)	0.19		0.65	

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

Table 8. The number of small-sized tubers, medium-sized tubers, and big-sized tubers per hill as influenced by varieties and mulching of potato at Dailekh, Nepal in 2022

Treatment	No. of small tuber (<50gm)	No. of medium tubers (50-100gm)	No. of big tubers (>100gm)
Mulching			
Mulch	2.96	9.98	2.68a
Control	2.38	9.37	2.087b
SEM	0.28	0.3	0.3
LSD (0.05)	0.72	1.604	0.32
CV (%)	17.20	10.60	8.50
F-test	ns	ns	*
Varieties			
Khumal Seto-1	2.07d	9.57bc	3.083a
Desiree	2.77b	10.33a	2.37bc
Cardinal	2.95ab	9.50bc	2.15c
Kufri- Jyoti	3.15a	9.64b	1.83d
C-88	2.43c	9.35c	2.48b
SEM	0.19	0.17	0.21
LSD (0.05)	0.22	0.46	0.301
CV (%)	7.30	3.90	10.30
F-test	***	**	***
Interaction			
F-test	ns	ns	ns

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

Table 9. Total cost of cultivation (NRs./ ha), gross return (NRs./ha), net return (NRs./ha), and B:C ratio as influenced by varieties and mulch conditions of Potato at Dailekh, Nepal in 2022

Treatment	TCC (NRs./ha)	Gross return (NRs./ha)	Net return (NRs./ha)	B:C Ratio
Mulching				
Mulch	395850	1300840a	904990a	3.283a
Control	341350	1048720b	707370b	3.07b
SEM	0	126060	98810	0.11
LSD (0.05)	0	83647.5	83647.5	0.1
CV (%)	0	4.50	6.60	4.20
F-test	***	**	**	*
Varieties				
Khumal Seto-1	368600	1283300a	914700a	3.48a
Desiree	368600	1218700b	850100b	3.29b
Cardinal	368600	1156100c	787500c	3.13c
Kufri- Jyoti	368600	1079400d	710800d	2.92d
C-88	368600	1136400c	767800c	3.07c
SEM	0	35089.08	35089.08	0.1
LSD (0.05)	0	39329.8	39329.81	0.11
CV (%)	0	2.70	4	2.60
F-test	ns	***	***	***
Interaction				
F-test	ns	ns	ns	ns
Grand Mean	368600	1174780	806180	3.18

Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, TCC= Total cost of cultivation (NRs./ha) needed to be added, DAS= Days After Sowing, ns= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance

the number of small-sized tubers, medium-sized tubers, and large-sized tubers. The number of small-sized tubers was significantly higher for Kufri-Jyoti (3.15), which was statistically at par with the Cardinal (2.95), followed by Desiree (2.77). The number of small-sized tubers was the least for Khumal Seto-1 (2.07), which was statistically different from C-88 (2.43). The number of medium-sized tubers was significantly higher for Desiree (10.33), followed by Kufri-Jyoti (9.64), which was statistically similar with Khumal Seto-1 (9.57), and Cardinal (9.50). The number of medium-sized tubers was the least for C-88(9.35). The numbers of big-sized tubers were found significantly higher for Khumal Seto-1(3.083), followed by C-88 (2.48) which is statistically at par with Desiree (2.37). The number of big-sized tubers was the least for Kufri-Jyoti (1.83), which was statistically different from Cardinal (2.15). Differences in tubers' size might be due to genetic and environmental factors. Genetic and growth pattern variations could be the cause of the variations in tuber numbers between cultivars. Similar results were noted by Panthi et al. (2019). Masarirambi et al. (2012) also found a significant difference in tuber size per plant in their study. These differences among different varieties might be due to appropriate climatic conditions for general adaptation, genetics of the variety as well as better quality of propagating material (Eaton et al., 2017).

3.10 Economic analysis

Each treatment was taken into consideration for the analysis of the economy along with the corresponding marketable yield with prevalent prices per unit output. (Table 9) shows the details of the cost of production, gross benefit, net benefit, and B:C ratio. The economic analysis is done based on the current cost and prices. Benefit-cost (B:C) ratio was significantly influenced by mulching and varieties, as shown in Table 15. In the case of the first factor, the B:C ratio was found to be significantly higher in the mulch condition (3.28) as compared to the control (3.07). In the case of the second factor, too, B:C ratio was found to be significantly higher for Khumal Seto-1 (3.48), followed by Desiree (3.29) and Cardinal (3.13). B:C ratio was found least for Kufri-Jyoti (2.92), which is statistically different from C-88 (3.07). The insignificant result on B:C ratio was found on the interaction between two factors, but the highest B:C ratio was found in Khumal Seto-1 under mulching as compared to other treatment combinations.

4 Conclusion

The use of appropriate mulch materials is one plausible technique for preserving soil moisture and potato tuber quality. The growth and yield attributing parameters such as plant height, the number of aerial stems per plant and leaves per stem, the stem diameter, the number of branches, and the canopy diameter of the potato plant, yield, and economics of production were significantly different for the mulched condition and varied forpotato varieties as well. Khumal Seto-1 under plastic mulching showed the best performance under the Dailekh-like climate. Under mulching practice, the highest total yield was observed in Khumal-Seto-1 (25.32 t/ha), followed by Desiree (24.39 t/ha). The potato production with black plastic mulch was found to be the most economical due to its highest gross return, net return, and B:C ratio compared to control conditions. Variety Khumal Seto-1 had significantly higher marketable tuber yield and total tuber yield under plastic mulching. Therefore, based on the study's findings, the cultivation of the Khumal Seto-1 variety under plastic mulching is recommended to increase potato tuber yield in locations with similar conditions to Dailekh, Nepal. Moreover, future studies should focus on the validity of plastic mulch, with comparable tests conducted in different locations and seasons using several readily available and affordable mulching materials.

Conflict of Interest

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

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