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Effect of Various Mulching Methods on Growth and Yield Parameters of Potato (*Solanum tuberosum*) Varieties in Achham, Nepal

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Abstract A field experiment was conducted from February to June 2022 at Thulasen of Mangalsen Municipality-Achham, Nepal to determine the suitability of various mulching materials on the growth and yield of different potato varieties. Two major varieties i.e. Khumal Seto and Cardinal grown with four types of mulching material (Black plastic mulch, Silver plastic mulch, Organic mulch, and Control) were set up in a Randomized Complete Block Design (RCBD) with three replications. The vegetative parameters evaluated were germination percentage at 20 and 30 DAP, plant height, aerial stem number, plant spread, and stem girth at 60, 75, and 90 days after planting (DAP). In contrast, the reproductive parameters including tuber number/m^2, yield (kg/m^2) and graded tuber (number/m^2) for three grades were taken after potato harvest. Data entry and analysis were done in MS- Excel and R-studio software respectively. Findings revealed that at a 5% level of significance, a significant difference was found in the interaction effect of variety and mulching material respective to germination, height, average yield, and tuber numbers for (>100 gm). Khumal Seto in black plastic mulch was found significantly superior for germination percentage at 30 DAP (93.33%), plant height (40.87 m), and yield parameters like average tuber yield (5.10 kg/m^2) and tuber number above 100 gm (12.67). In addition, the Khumal seto variety had greater stem girth (3.03 cm) and tuber yield while the Cardinal variety had a maximum number of stems (11.17). The highest plant spread (48.13 cm) and stem girth (3.10 cm) were observed in black plastic mulch and the lowest was in control in 60, 75, and 90 DAP. Khumal Seto in black plastic mulch was found to be the most effective treatment for increasing the overall production of potatoes.

Keywords Cardinal; Khumal seto; Mulching; Potato (*Solanum tuberosum*)

Potato (*Solanum tuberosum*) is an important commercial vegetable and food crop of hills and Himalayan region in Nepal. It occupies the fifth position in area coverage, second in total production, and first in productivity among the food crops grown in Nepal. Potato is a temperate crop that can be grown from an altitude of 300 m to 1,800 masl. The area under potato cultivation in Nepal is 198,256 ha with an average production and productivity of 3,410,829 tons and 17.2 t/ha respectively (MOALD, 2021/22). Potato solely accounts for 6.57% of the Agricultural Gross Domestic Product (AGDP) and 2.17% Gross Domestic Product (GDP) (MoF, 2019).

Achham covers an area of 1,692 km^2 (653 sq. miles) and extends from the latitude of 280°46' North to a longitude of 810°32' East. It has 90% area of mid-hill and 10% high hill. Potato is mostly cultivated among all crops in a land of 1,012 ha with a total production of 14,674 mt and yield of 14.5 mt/ha in Achham district (ABPSD, 2021/22). It has a pivotal role as a cash crop to address food insecurity and reduce poverty among smallholder farmers in developing countries like Nepal (Timilsina et al., 2013). It works as a complete food as it contains carbohydrates, proteins, vitamins B, and C, and minerals like phosphorus, calcium, and iron. Mulching has become an essential agronomic practice that modifies the physical environment of the soil, suppresses weeds, checks the application of herbicide effect, and improves soil fertility (Prem et al., 2020). It also defines the increased yield and productivity of potatoes. Mulching also has a significant influence on the growth and yield of potatoes (Begum and Saikia, 2014). Mulching also promotes soil water infiltration and crop water availability which helps to improve soil biodiversity and environmental benefits (Memon et al., 2017). Mulches function as cover crops to reduce tillage operations that have some ecological advantages over conventional land preparation

tasks causing minimum alterations in the soil environment (Ahmed et al., 2017). Mulching also contributes to higher water use efficiency by plants, higher yields, and greater economic benefits.

Thus, our aim in the study was to assess the effectiveness of mulching materials on enhancing the growth parameters and yield of selected varieties of potato at the field condition of Achham, Nepal.

1 Materials and Methods

1.1 Experiment design

An experiment was conducted from Feb to June 2022 under the Prime Minister Agriculture Modernization Project, Project Implementation Unit, Achham, Nepal. The experiment was carried out in two factorial RCBD designs with varieties (Khumal seto and Cardinal) and mulching materials (Table 1). In total, there were eight distinct treatments (Table 2).

Table 1 Factors details used in the study

Factor	Symbol
Variety	
Khumal Seto	V_1
Cardinal	V_2
Mulching materials	
Black plastic mulch	A_1
Silver plastic mulch	A_2
Organic mulch	A_3
Control	A_4

Table 2 Treatment details used in the study

S.N	Name of treatment	Symbol	Treatment
1.	Khumal Seto + Black plastic	V_1*A_1	T_1
2.	Khumal Seto + Silver Plastic	V_1*A_2	T_2
3.	Khumal Seto+ Organic Mulch	V_1*A_3	T_3
4.	Khumal Seto + Control	V_1*A_4	T_4
5.	Cardinal + Black plastic	V_2*A_1	T_5
6.	Cardinal + Silver Plastic	V_2*A_2	T_6
7.	Cardinal + Organic Mulch	V_2*A_3	T_7
8.	Cardinal + Control	V_2*A_4	T_8

1.2 Treatments

The ploughing was done about 3-4 times followed by harrowing to make soil free from large soil clods and weeds before sowing. Beds were made up of (1.5*0.5*0.3) m size, ridges and furrows were made on it and mulches were kept above ridges. Each treatment plot was (3.5*1.5) m in size. The spacing was 70 cm × 30 cm (row to row × plant to plant). Seed rate was 1.5 t/ha. For sowing, graded, medium-sized tubers (about 30-50 gm), healthy and well-sprouted seed tubers were selected. Different mulching materials as per the treatments were placed in ridges in the soil and holes were made in them at 30 cm spacing according to plant distance. Planting of tubers was done in the holes at a 15 cm depth in the soil. Each treatment had 5 rows and 5 plants per row thus, in total there were 25 potato tubers of uniform size per treatment.

In the case of organic mulch, first tuber sowing was performed and then organic mulch was placed over it. Urea: P_2O_5: K_2O was added in the following proportions: 132.3: 217.4: 100 kg and FYM at 30 t/ha respectively as per the recommended dose for mid hills of Nepal (MOALD, 2020). Irrigation supply was done at intervals to the crop's needs. Weeding was practiced three times at periodic intervals. Harvesting of potato was done after the stem and leaves turned brown after 98 days of sowing.

In each treatment, five plants were selected as samples and evaluated for study. The data collection was done for different parameters like days for germination, plant height (cm), stem girth (cm), stem no., plant spread (cm), tuber weight (kg/m^2), and tuber number per grade. Total healthy germinated seedlings out of the total were counted to find the percentage of germination. Plant height was measured from the soil surface to the topmost growth point by using a scale and stem girth by rolling the tape around the plant stem. Also, canopy cover was obtained by measuring the diagonal distance. Data collection was done at 60, 75, and 90 days after sowing. Yield was noted from each sampled plant in kg/m^2, and the average number of tubers per m^2 was also determined. Tubers after harvest were graded in different size ranges and were evaluated.

1.3 Statistical analysis

The collected data was systematically entered in MS Excel and was analyzed using the software, R- Studio. Duncan's multiple Range Test (DMRT) was used to separate and compare means at a 5% level of significance (Gomez and Gomez, 1984).

2 Results and Discussion

2.1 Growth parameters

2.1.1 Percentage of germination

The ANOVA results showed germination percent by both variety and mulching methods was significantly different at the 5% level (Table 3). The Khumal Seto variety had quick and high germination (83.33%) while the Cardinal variety exhibited a lower rate (61.33%) at 30 DAP. For the mulching, the rate of germination was high in black plastic mulching (92) followed by silver mulching (83.33%), organic mulching (65.67%), and control (58.33) at 30 DAP. Also, the results showed that the interaction had a significant effect on germination percentage (Table 4). The variety Khumal Seto demonstrated a higher germination percentage (93.33%) in black plastic mulch as compared to others. Plastic mulching expedited the potato germination and emergence by elevating the topsoil temperature. Black plastic mulches effectively maintain the optimal temperature by the absorption of solar radiation and enhance crop emergence (Li et al., 2017). Notably, black polyethylene mulch has been found to elevate soil temperature by up to 9 degrees Celsius (Kumari, 2012).

Table 3 Effect of varieties and mulching method on growth parameters of potato

Treatment	Germination (%)	Height (cm)	Stem number	Stem girth (cm)	Plant spread (cm)
Variety					
Khumal Seto	88.33^a	35.81^a	5.91^b	3.03^a	44.12^a
Cardinal	61.33^b	25.11^b	11.17^a	2.49^b	40.86^a
LSD (0.05)	8.51	2.73	1.48	0.05	4.54
SEM (±)	0.06	0.64	0.48	2.81	1.5
F probability	<0.001	<0.001	<0.001	<0.001	NS
CV%	9.68	7.24	19.85	6.05	26.9
Mulching method					
Black plastic mulch	92^a	34.82^a	9.5^a	3.10^a	48.13^a
Silver plastic mulch	83.33^a	33.70^a	8.66 ^{a}	2.88^b	45.93^{ab}
Organic mulch	65.67^b	28.43^b	8.5 ^{a}	2.63^c	40.58^{bc}
Control	58.33^b	24.90^c	7.5^a	2.44^c	35.33^c
LSD (0.05)	12.04	2.82	2.09	0.21	6.42
SEM (±)	0.08	0.90	0.69	0.07	2.11
F probability	<0.001	<0.001	NS	<0.001	<0.01
CV%	12.99	7.24	19.85	6.05	12.21
Grand mean	74.83	30.46	8.54	2.76	42.5

Note: ± Means of 3 replications. Means in column with same superscript is not significantly different by DMRT at 0.05 level, LSD: Least Significant Difference, CV: Coefficient of variation, SEM (±): Standard error of mean

Table 4 Interaction effect of varieties and mlching method on different parameters of potato

Treatment	Germination (%)	Height (cm)	Tuber weight (kg/m^2)	Tubers no (>100gm)
Khumal Seto*Black plastic mulch	93.33^a	40.87^a	5.10^a	12.67^a
Khumal Seto*silver plastic mulch	90.67^a	36.23^b	4.3^b	8.33^b
Khumal Seto*Organic mulch	82.67^a	34.3^{bc}	3.35^c	8.67^b
Khumal Seto*Control	86.67^a	31.87^{cd}	2.19^d	3.33^c
Cardinal*Black plastic mulch	90.67^a	28.77^d	2.16^d	1^{cd}
Cardinal*silver plastic mulch	76^a	31.16^{cd}	1.88^d	0.33^d
Cardinal*Organic mulch	48.67^b	22.56^e	1.59^{de}	1.33^{cd}
Cardinal*Control	30^c	17.93^f	0.98^e	0^d
LSD (0.05)	2.67	3.86	0.67	2.67
SEM (±)	5.61	1.27	0.22	0.88
F probability	<0.01	<0.05	<0.01	<0.01

Note: ± Means of 3 replications. Means in column with same superscript is not significantly different by DMRT at 0.05 level, LSD: Least Significant Difference, CV: Coefficient of variation, SEM (±): Standard error of mean

2.1.2 Plant height

The experimental data showed that the Khumal seto variety had the tallest plants (35.81 cm) while the Cardinal had the shortest (25.11 cm) with a significant difference at the 5% level (Table 3). Statistically similar mean height was observed among black plastic (34.82 cm), silver plastic mulch (33.7 cm), and as well in organic mulch (28.4 cm) and control (24.9 cm). The increased height in mulched plants is likely attributed to a significant difference also in the interaction between the two factors (Table 4). Khumal Seto with black plastic mulching exhibited greater height (40.87 cm), while the control effect of the Cardinal variety showed smaller height (17.93 cm). The results are also supported by (Bharati et al., 2020), who explained that mulching facilitates the soil moisture availability and maintenance of soil temperature which increases plant height especially black plastic mulch. Also, Joshi et al. (2020) concluded that increased plant height was observed in mulch conditions than in control.

2.1.3 Number of stems and stem girth

The results showed that the number of stems per tuber and stem girth was significantly different among varieties at the 5% level (Table 3). The Cardinal variety showed a maximum number of stems (11.1) while a minimum number of stems was observed in the Khumal Seto variety (5.91). Such a response was also reported by (Paudel et al., 2023). However, the difference in stem numbers was not statistically significant in the case of mulching materials.

Stem girth was also higher in the Khumal seto variety (3.03 cm) than Cardinal (2.49 cm) (Table 3). Regarding mulching, the highest stem girth was recorded in black plastic mulch (3.10 cm) as compared to others. The experiment led by (Bhandari and Bhandari, 2021) on the effect of mulching materials on broccoli also described root and shoot growth of plants as favored from plastic mulch.

2.1.4 Plant spread

The plant spread of potatoes was significantly influenced by different methods of mulching material at the 5% level of significance but not by a variety and interaction effects (Table 3). The ANOVA result showed that the highest plant spread was observed in black plastic mulch (48.13 cm) followed by silver plastic (45.93 cm) and organic mulch (40.58 cm) while the lowest was observed in the control treatment (35.3 cm). The observed response was primarily a result of the soil's physiochemical and biological enhancements under mulch conditions, providing favorable temperature and moisture levels, improved nutrient availability, and increased microbial activity (Bharati et al., 2020). Mulched plots exhibited significantly higher nitrogen and phosphorus content, along with increased nutrient uptake, compared to their un-mulched counterparts, essential for the proper vegetative growth of plants (Hundal et al., 2000).

2.2 Yield parameters

2.2.1 Tuber number

The details of ANOVA revealed a significant difference in tuber count attributed to mulching at a 5% level of significance (Table 5). The highest tuber number was recorded in black plastic mulching (83.17), which is statistically similar to silver plastic (81.17) and organic mulching (71.67), while the lowest tuber count was observed in the control treatment (54.67). Tuber count was higher in mulched conditions compared to un-mulched conditions, as mulching aids in temperature regulation and maintains favorable environmental conditions, which aligns with the findings of (El-Beltagi et al., 2022).

Table 5 Effect of varieties and mulching methods on yield parameters of potato

Treatment	Tuber number	Weight (kg/m$^{2)}$	Grading		
			(<50 gm)	(50-100 gm)	(>100 gm)
Variety					
Khumal Seto	75.75^{a}	3.74^{a}	44.67^{b}	16.67^{a}	8.25^{a}
Cardinal	65.58^{a}	1.66^{b}	68.83^{a}	6.25^{b}	0.67^{b}
LSD (0.05)	8.1	0.11	9.34	3.54	1.33
SEM (±)	2.67	0.66	3.07	1.17	0.44
F probability	NS	<0.001	<0.001	<0.001	<0.001
CV%	12.73	14.28	18.79	35.28	34.16
Mulching method					
Black plastic mulch	83.17^{a}	3.63^{a}	-	15^{a}	6.83^{a}
Silver plastic mulch	81.17^{a}	3.09^{b}	-	14^{ab}	5^{ab}
Organic mulch	71.67^{a}	2.47^{c}	-	9.33^{bc}	4.33^{b}
Control	54.67^{b}	1.59^{d}	-	7.50^{c}	1.67^{c}
LSD (0.05)	11.46	0.48	-	5.00	1.89
SEM (±)	3.78	0.16	-	1.65	0.62
F probability	<0.001	<0.001	-	<0.05	<0.001
CV%	12.73	14.28	-	35.28	34.16
Grand mean	72.67	2.7	56.75	11.46	4.45

Note: ± Means of 3 replications. Means in column with same superscript is not significantly different by DMRT at 0.05 level, LSD: Least Significant Difference, CV: Coefficient of variation, SEM (±): Standard error of mean

2.2.2 Tuber weight

Tuber weight is one of the yield attributing parameters with a significant difference observed in tuber weight as shown in (Table 5) at a 5% level of significance based on both the varietal effect and mulching practices, with Khumal Seto exhibiting higher weight (3.74 kg/m^2) and Cardinal showing lower weight (1.66 kg/m^2). Similarly, black plastic mulch resulted in the highest tuber weight (3.63 kg/m^2), followed by Silver plastic (3.09 kg/m^2) and organic mulching (2.47 kg/m^2), whereas the control treatment exhibited the lowest weight (1.59 kg/m2). In the case of interaction between the first and second factors, there was a significant difference in tuber weight (kg/m^2) (Table 4). The variety Khumal Seto in black plastic mulching had the highest tuber weight (5.10 kg/m^2) followed by the Khumal Seto variety in Silver mulch (4.3 kg/m^2), organic mulch (3.35 kg/m^2) and control (2.19 kg/m^2). The tuber weight in control was found statistically similar to the cardinal variety in black (2.16 kg/m^2) and silver plastic mulching (1.88 kg/m^2). The lowest tuber weight was observed for cardinal variety in the control treatment (0.98 kg/m^2). Manganelli (2017) explained the higher yield to an expanded photosynthetic area facilitated by colored plastic mulch, influencing the allocation of photosynthates to harvestable organs. The findings also correlate with Kadar et al. (2017), who explained that the increased yield resulted from an effective moisture extraction ratio in deeper soil layers under mulching, enhancing total available soil moisture. Moreover, the perforations in the plastic aided root zone aeration and evaporation of excess water, promoting tuber growth.

2.2.3 Grading

Grading was done in potatoes based on weight. It was categorized into 3 sizes, small-sized tuber (<50 gm), medium-sized tuber ranging (50-100 gm), and large-sized tuber ranging (> 100 gm). The ANOVA results showed a significant difference in graded tuber numbers of 0-50 gm, 50-100 gm, and above 100 gm due to varietal effect at a 5% level of significance (Table 5). Maximum tuber number (< 50 gm) was observed in the cardinal variety (68.83/m^2) while the minimum for the Khumal Seto variety (44.67/m^2). But, the maximum number of (50-100) gm and (>100) gm tubers were observed in the Khumal Seto variety (16.67, 8.25/m^2) and minimum in the cardinal variety (6.25, 0.67/m^2) respectively. The mulching had a significant effect on tuber number for tubers graded under two categories, (50-100) gm and (>100) gm, with the highest number in black plastic mulch than others, whereas it was not significant for the grade (<50 gm). There was no statistically significant difference in the numbers of the graded tuber of size (<50 gm) and (50-100 gm) from the interaction.

However, experimental data presented that graded tuber numbers significantly vary for size (>100 gm) due to the interaction effect (Table 4). The maximum number was observed for the variety Khumal Seto in black plastic mulching (12.67) followed by organic mulching (8.67) which was statistically similar to silver plastic mulching (8.33) in Khumal Seto variety. In addition, the Khumal Seto variety in the control treatment (3.33) had higher tuber numbers of (>100 gm) grade than that of the cardinal variety in black (1), silver plastic (0.33) and organic mulching (1.33). Tuber numbers for (>100 gm) grade were null for cardinal variety in the control treatment. (Kadar et al., 2017) findings explained that black mulch provides proper aeration, moisture, and optimal temperature in the root zone producing a good number of medium and large-sized tubers. The increased number of large-sized tubers in black plastic mulch is also attributed to elevated soil temperature, reduced weed competition, improved nutrient uptake, and better soil moisture regimes (Ibarra-Jiménez et al., 2011).

3 Concluding Remarks

This study explored the impact of various mulching materials on the growth and yield of two potato varieties, Khumal Seto and Cardinal, in the Achham district of Nepal. The findings showed that Khumal seto variety and Black plastic mulch had interactive and additive effects in a significant increase in potato yield. The Khumal Seto variety of potatoes showed superior performance in vegetative growth than the cardinal variety. For the cardinal variety, the yield was too low and its tuber size above 100 gm was null in control conditions. Additionally, black plastic mulch was found to be a more suitable mulching material compared to silver plastic mulch and organic mulch for all the parameters.

Thus the results confirm that mulching materials significantly affect the potato's growing environment by regulating the soil temperature, moisture and optimizing nutrient utilization, thereby increasing yield. It underscores the importance of selecting appropriate mulching materials to enhance agricultural productivity of specific potato varieties in particular regions of Nepal.

Future research should prioritize the role of mulching in disease and pest management to recommend mulch as an integrated beneficial apporach to potato cultivation.

Author's contributions

SG was involved in identifying the research idea and designing the experiments. SG along with PB, AR, NA, and PG supported during the whole research, data analysis and drafting of the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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