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RESEARCH ARTICLE
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Performance of Potato Variety Rolpa Local (*Solanum tuberosum* L.) under Different Mulching Conditions and Zinc Levels at Rolpa, Nepal

Rendimiento de la variedad de papa Rolpa Local (*Solanum tuberosum* L.) bajo diferentes condiciones de cobertura y niveles de zinc en Rolpa, Nepal

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Abstract

Use of the right mulching techniques is a crucial first step in replacing the issues with irrigation and weed infestation in potato production. To assess the performance of potatoes at two doses of zinc under different mulching conditions, a field experiment was laid out in a two-factorial, randomized complete block design (RCBD) comprising eight treatments with three replications each. The variety used was Rolpa local. The first factor consisted of three mulching materials: plant residue (M1), black plastic (M2), silver on black plastic (M3), and a control plot (M_0), whereas the second factor compromised two levels of zinc (0 kg/ha and 4 kg/ha). Both plastic mulches were found to have a significant influence on germination rate during the field research; however, all other observations for growth and yield parameters, such as plant height, tuber number, tuber weight, and yield per plant, were significantly superior in the silver on black plastic. The highest germination percentage was observed in black plastic mulch (94.67 %). However, all other observations for growth and yield parameters were found to be significantly superior in the silver on black plastic mulch condition, with plant height (87.28 cm), leaf count (145.70), number of tubers per plant (22.16), and a total yield of 21.83 t/ha. Similarly, all the yield-attributing characters were found to be significantly different among zinc levels, with the highest total yield of 17.70 t/ha at 4 kg/ha of zinc. Silver on black plastic mulch and 4 kg/ha of zinc level resulted in the highest benefit-cost (B:C) ratios of 3.18 and 2.23, respectively. The results showed that using silver on black plastic mulch with a zinc level of 4 kg/ha improved both vegetative growth and potato yield, with favorable B:C ratios resulting in higher profitability. Thus, to maximize profit, it would be advantageous to utilize silver on black plastic mulch with 4 kg/ha of zinc.

Key word: *B:C ratio; Canopy diameter; Germination percentage; Mulching; Silver on black plastic; Tuber yield; Zinc*

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Resumen

El uso de las técnicas de acolchado adecuadas es un primer paso crucial para solucionar los problemas de riego y de infestación de malas hierbas en la producción de patatas. Para evaluar el rendimiento de las patatas con dos dosis de zinc en diferentes condiciones de acolchado, se realizó un experimento de campo en un diseño de bloques completos aleatorizados (DCCA) bifactorial que comprendía ocho tratamientos con tres repeticiones cada uno. La variedad utilizada fue Rolpa local. El primer factor consistió en tres materiales de acolchado: residuos vegetales (M1), plástico negro (M2), plata sobre plástico negro (M3), y una parcela control (M0), mientras que el segundo factor comprometió dos niveles de zinc (0 kg/ha y 4 kg/ha). Ambos acolchados plásticos influyeron significativamente en el porcentaje de germinación durante la investigación de campo; sin embargo, todas las demás observaciones de los parámetros de crecimiento y rendimiento, como la altura de la planta, el número de tubérculos, el peso de los tubérculos y el rendimiento por planta, fueron significativamente superiores en el plástico plata sobre negro. El mayor porcentaje de germinación se observó en el acolchado de plástico negro (94.67 %). Sin embargo, todas las demás observaciones para los parámetros de crecimiento y rendimiento resultaron ser significativamente superiores en la condición plata sobre acolchado de plástico negro, con altura de planta (87.28 cm), recuento de hojas (145.70), número de tubérculos por planta (22.16), y un rendimiento total de 21.83 t/ha. Del mismo modo, todos los caracteres atributivos del rendimiento resultaron ser significativamente diferentes entre los niveles de zinc, con el mayor rendimiento total de 17.70 t/ha a 4 kg/ha de zinc. La plata sobre acolchado de plástico negro y el nivel de zinc de 4 kg/ha dieron lugar a las relaciones beneficio-coste (B:C) más elevadas, de 3.18 y 2.23, respectivamente. Los resultados mostraron que el uso de plata sobre acolchado de plástico negro con un nivel de zinc de 4 kg/ha mejoró tanto el crecimiento vegetativo como el rendimiento de la patata, con ratios B:C favorables que resultaron en una mayor rentabilidad. Así pues, para maximizar el beneficio, sería ventajoso utilizar plata sobre acolchado de plástico negro con 4 kg/ha de zinc.

Palabras clave: *relación B:C; diámetro del dosel; porcentaje de germinación; Acolchado; Plata sobre plástico negro; rendimiento de tubérculos; Aplicación de zinc*

Introduction

The potato (*Solanum tuberosum* L.) is the fourth-largest crop grown in the world after maize, wheat, and rice and the third-most significant crop in terms of human consumption (Yuan & Sun, 2022). Potatoes improve the livelihood and food security of impoverished farmers, and hundreds of millions of people in developing nations rely on potatoes as their primary source of food (International Potato Center (CIP, 2022); Devaux et al., 2014). It is one of Nepal's most significant staple crops (Timsina et al., 2011). It is considered a key cash crop for alleviating poverty and tackling food insecurity among smallholder farmers in developing nations like Nepal (Bista et al., 2013). At present, the area under potato cultivation in Nepal is about 198,788 ha, with a productivity of 16.73 t/ha (Ministry of Agriculture & Livestock Development [MoALD], 2021). Potato is essential in the Nepalese context, as it is utilized as a secondary food as part of a vegetable in the Terai region and as a staple food in the upper physiographic regions of the country. However, many factors impede potato production, such as lack of quality seeds and fertilizers, improper storage facilities, labor shortages, undulated topography affecting transportation and marketing, lack of pest and disease management, and crop-weed competition for sunlight, nutrients, soil moisture, and space (Maldonado et al., 1998; Yadav et al., 2015).

Potato growth and yield are related to soil quality and environment, which are influenced by various factors, including complex soil physical and chemical properties, climatic conditions, enzyme activities, microbial abundance, and diverse production strategies (Fan et al., 2019; Qin et al., 2017). Surface mulch is one of the most economical and important factors of soil protection technology because it affects soil temperature and water potential, which can increase the performance of crops by lowering surface evaporation and preserving soil moisture (Dvořák et al., 2012; Qin et al., 2018; Shelton et al., 1995). Mulching reduces the problem of weed infestation as it prevents the photosynthesis of weeds (Ranaivoson et al., 2018) and minimizes the leaching loss of nutrients (Dong et al., 2019). Mulching helps in maintaining a better growing environment like soil, temperature, and moisture, which ultimately leads to a higher yield (Kader et al., 2017). Using the right mulching techniques is a crucial first step in addressing the issues with irrigation and weed infestation in potato production. Hatfield et al. (2001) observed a reduction in soil water evaporation of up to 50% due to mulching, which limited the requirement for crop irrigation. Memon et al. (2017) reported the improvement of soil biodiversity and environmental advantages due to mulching, as it increased soil water infiltration and crop water availability. The hydrothermal conditions of the soil are influenced by plastic mulching, which raises soil warmth and reduces soil water evaporation (Wang et al., 2005). Mulching resulted in a higher germination rate and stronger seedlings, which raised the number of stems and branches per plant, resulting in a higher number of tubers at tuber initiation (Ahmed et al., 2017). Mulching with black plastic has been shown to improve potato stem number, plant height, and yield (Bharati et al., 2020). Black polyethylene mulch can increase soil temperature up to 9 °C, which stimulates quicker germination (Kumari, 2012). Black and silver-colored plastic mulches are reported to improve crop growth, yield, and quality more than other colored mulches (Amare & Desta, 2021). Black plastic mulches were reported to have increased soil temperature, reduced weed competition, improved nutrient uptake, and improved soil moisture regimes, which resulted in more large-sized tubers being produced (Ibarra-Jiménez et al., 2011). Silver plastic promoted the optimal root temperature for plant growth with the greatest efficiency of nitrogen utilization and the greatest tuber yield, whereas higher temperatures in black plastic depressed nitrogen metabolism as well as yield (Ruiz et al., 1999). Compared to black and white plastic mulch, silver plastic mulch had a greater PAR (photosynthetically active radiation) reflectance, and such increased PAR reflection by silver plastic mulches lowered root zone temperature, resulting in optimum soil temperature and reducing water loss (Amare & Desta, 2021). Singh et al. (2015) reported that using plant residue as mulching material improved soil moisture by reducing soil water evaporation as a result of less solar radiation reaching the soil surface. Further, crop residues (or plant litter) on the soil surface reduced soil erosion, improved soil quality, boosted water infiltration, and lowered the quantity of nutrients and pesticides that reached streams and rivers (Delgado, 2010).

Similarly, zinc (Zn) is an important plant mineral whose lack not only limits crop productivity but also has implications for human nutrition and health. Zinc plays numerous key roles in plant growth, and a consistent and continuous supply is required for optimum growth and output. Zinc deficiency impacts root growth, resulting in decreased water and nutrient absorption from the soil, resulting in reduced plant growth, nutrient composition, and yield (Hacisalihoglu et al., 2004). It is essential for enhancing the quantity and quality of potato tubers. An all-India coordinated study on potato and micronutrient response showed that the yield response of potatoes to applied Zn fertilizer varies with the soil type, variety, quantity of other major nutrients applied to the soil, and finally the method of application (Mondal et al., 2015). According to Sarkar et al. (2018), zinc loading in potatoes, both foliar and soil-applied, boosts Zn content in potato tubers by 3–4 times, which is much greater than most generally recognized crops. Zinc is critical for potato physiology, productivity, and post-harvest quality, and its application in potatoes increased yield, average tuber weight, number of tubers, quality indices, and post-harvest indices (Banerjee et al., 2017). Zn fertilization has been shown to increase ascorbic acid concentration while decreasing tyrosine and total phenol levels in tubers, improving processing quality (Sarkar et al., 2018).

Over-use of macronutrients (N, P, and K) in potato production results in serious depletion of different micronutrients in soil reserves (Banerjee et al., 2017). Also, diseases, insects, weeds, and other pests cause significant losses in agricultural yield and quality each year, which can be reduced by using suitable mulching and field management techniques, including appropriate fertilization (Bharati et al., 2020). The combination of zinc sulfate and mulching may be the most effective strategy for conserving water and increasing vegetable yield (Singh et al., 2019). Improved growth characteristics as a result of zinc soil application and mulching could be attributed to increased photosynthetic and other metabolic activity, which leads to a rise in numerous plant metabolites responsible for cell division and elongation (Hatwar et al., 2003). A lot of independent studies have been done to study the effects of N, P, and K fertilizer and mulching on potato production and quality in different areas of Nepal. However, there haven't been many studies attempting to determine the appropriate Zn dose for potato cultivation under various mulch conditions. Therefore, figuring out the right Zn dosage for potato production under different mulching treatments is a crucial aspect of improving potato production in Nepal.

Materials and Methods

Description of the experimental site

A field experiment was conducted during February to July, 2022 in Rolpa municipality-4, Liwang which is geographically located at 28.3000° N latitude and 82.6333° E longitude. The elevation of the study area was 1896 masl. Geographically, the experimental location falls in the mid-hill region of Lumbini Province. In Rolpa, area under cultivation is 1280 ha with production of 20 860 t and yield of 16.30 t/ha.

Physico-chemical characteristics of the experimental soil

Representative soil samples were taken at a depth of 15 cm to 25 cm from different parts of experimental fields using a soil sampling auger, and analysis of the sample soil was performed. The soil type was found to be silt-loam. Chemical investigation revealed that the pH of the soil was acidic (6.4), the organic matter content was 2.1 % (moderate), the available nitrogen content was 181.3 kg/ha, the phosphorus content was 17.6 kg/ha, and the potassium content was found to be 126.4 kg/ha. The soil analysis indicated that Zn was slightly deficient at 1.16 mg/kg. The details of the physico-chemical analysis of the research plot's soil are depicted in Table 1.

Weather condition during course of experiment

Fortnight interval average data on different weather parameters i.e., maximum and minimum temperatures, precipitation and relative humidity recorded during the potato growing season is presented in Figure 1.

Experimental details

The experiment was conducted in open field conditions using the variety Rolpa local. The intention of using local variety was to promote local and to assess the compatibility of local variety with modern technologies of mulching and zinc application.

Table 1. Soil chemical properties of experimental site at Liwang, Rolpa, 2022

Soil parameter	Value	Methodology	Reference
Textural class	Silt loam	Soil textural triangle (USDA)	
pH	6.4	Glass-calomel electrode pH meter method (1:2 soil water ratio)	(Cottenie et al.,1982)
Organic carbon (%)	2.1	Wet oxidation method	Walkley and Black (1934)
Available N (kg/ha)	181.3	Hot alkaline KMnO4 Method	Subbiah and Asija (1956)
Available P (kg/ha)	17.6	0.5 M NaHCO3 extract	Olsen et al. (1954)
Available K (kg/ha)	126.4	Neutral N NH4OH extract	Hanway and Heidel (1952)
Available Zn (mg/kg)	1.16	DTPA-TEA (pH 6.4) extraction	Lindsay and Norvell (1978)

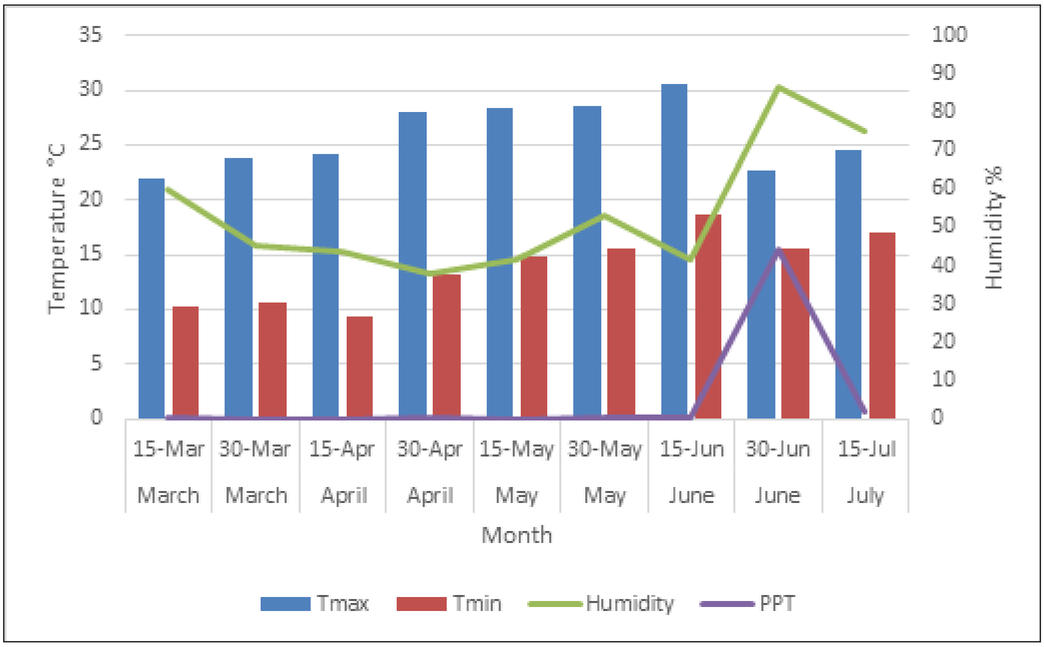

Figure 1. Weather condition during the course of experiment (NASA POWER, 2022)

Experimental Design

Design of the experiment was two factorial RCBD consisting of 3 replications and 8 treatments with well-spaced 45 cm × 20 cm between row to row and plant to plant respectively. Individual plot was of size 2.25 m^2 × 1 m^2 and the distance between two plots was 25 cm (Figure 2) .

Each plot accommodated 5 rows of plants, and 5 plants were present in each row of the plot with 45 cm × 20 cm of spacing, where the 1st and 5th rows were considered border rows and the middle 3 rows were taken as net plots. Five plants were taken as sample plants randomly from the middle row and were tagged for biometrical and phenological observations, and four random plants from the net plot were selected for harvesting data.

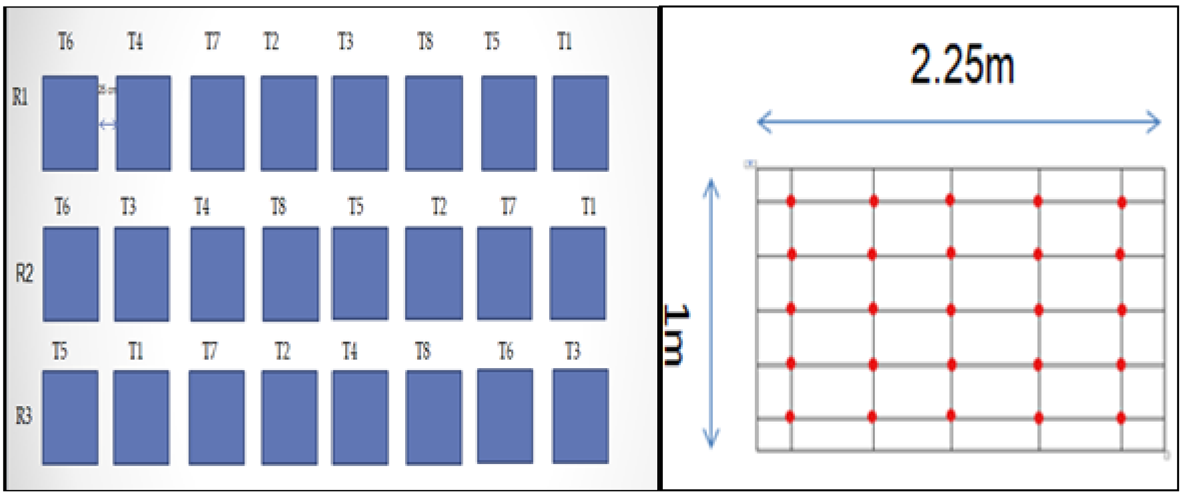

Figure 2. Layout of experimental field and individual plot

January to April 2023

Treatment Details

Two factor are used to generate treatment combination (Table 2, Figure 3).

Table 2. Treatment Combination

S.N.	Treatment(T)	Treatment Combination
1	Treatment 1(T1)	No mulching and no Zinc
2	Treatment 2(T2)	No mulching and 4 kg/ha of Zinc
3	Treatment 3(T3)	Plant residue and no Zinc
4	Treatment 4(T4)	Plant residue and 4 kg/ha of Zinc
5	Treatment 5(T5)	Black Plastic and no Zinc
6	Treatment 6(T6)	Black plastic and 4 kg/ha of Zinc
7	Treatment 7(T7)	Silver on black plastic and no Zinc
8	Treatment 8(T8)	Silver on black plastic and 4 kg/ha of Zinc

Factor 1: Mulching

M0: No Mulching

M1: Plant Residue

M2: Black Plastic

M3: Silver on black Plastic

Factor 2: Zinc

Z0: 0 kg/ha
Z1: 4 kg/ha
Zinc (For Zinc: Zinc Sulphate was used)

Cultural Practices

Field Preparation

The soil was harrowed until completely free of weed residue. Two plowings along with harrowing were done to make the soil soft, fine, well-drained, and well-aerated. Manually, stubbles of previous crops and weeds were removed prior to sowing potato tubers. The layout of the field was done by making 24 plots manually using tapes and spades.

Plant Population

Each plot consisted of 25 plants, and there were 600 plants in total in the whole experimental field.

Fertilizer Application

Urea, DAP (di-ammonium phosphate), and MOP (Muriate of potash) were used as per the national recommended dose, i.e., 140:220:100 kg/ha. A full dose of phosphorus, potassium, and half

Figure 3. Establishment of experimental plots: (M0) No Mulching, (M1) Plant Residue, (M2) Black Plastic and (M3) Silver on black Plastic

the amount of required nitrogen and zinc (zinc sulfate) at 4 kg/ha were applied as basal doses, whereas the remaining half of the nitrogen was applied 45 days after planting. Each plot was fed with 48.75 g of nitrogen, 48.75 g of phosphorus, and 22.5 g of potassium. The plot treated with zinc was fed with 2.75 g of zinc sulfate.

Seed rate and sowing

Healthy tubers of a local variety (Rolpa) were selected for the experiment. One tuber per hill was sown manually in all rows. On March 3, 2022, tubers were planted. Seed tubers were planted on raised beds.

Irrigation

The frequency of irrigation depends on the type of soil and the season's rainfall. Irrigation was applied as needed, and the requirement was fully maintained.

Earthing up and weeding

As the research was based on mulching materials, no earthing up or weeding was done.

Control Practices

Cutworm infestations were occasionally observed in the research field. The physical handpicking method was used to control cutworms. They were manually pulled out from the soil surface just below the base of the stem and destroyed.

Data Observation recorded in potato

Phenological traits such as germination percentage, plant height, number of leaves and canopy diameter and yield attributing characters such as total tuber number per hill, tuber weight, tuber diameter, length and circumference were recorded.

Economic analysis

Total cost of cultivation was calculated on the basis of local charges for different agro inputs viz. labor, fertilizer, mulching materials, seed tubers and other necessary materials. Economic yield of potato was expressed into gross returns (NRs/ha) on the basis of local market price and net return was calculated by deducting the cost of cultivation from the gross returns and expressed in NRs/ha. And then, the benefit-cost (B:C) ratio was calculated by using following formula:

Benefit cost ratio (B:C) = Gross returns/Total Cost of Cultivation

Statistical Analysis

The collected data was processed by MS Excel and analyzed by using R-studio. All the recorded data were subjected to analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) for mean separation. The significance differences among the means were tested using least significant difference (LSD) at 5 % level of significance (Gomez & Gomez, 1984).

Results and Discussion

Morphological parameters

Germination

The analyzed data revealed that the germination percentage at 30 DAP was significantly higher in the plot with mulching in comparison to the control. The highest germination percentage was observed in black plastic (94.67%), which was statistically similar to silver on black plastic (94.000%), while the germination percentage in plant residues (86.00%) was observed to be superior to the control (75.33%) plot. The higher germination in the mulch condition might be due to an increase in soil temperature as compared to the control condition. The increased soil temperature caused by the application of various plastic mulches resulted in faster germination, flowering, and physiological maturity in mulched conditions. Black plastic mulch can raise soil temperatures by up to 9 degrees Celsius, promoting faster germination (Bhatta et al., 2020; Kumari, 2012). Mulching has a more positive effect on germination at 30 DAP than the control condition (Mahmood et al., 2002). These results are also correlated with the findings of Ping et al.

(1994), who observed a faster germination rate in the plot with mulching.

Number of leaves

From the table of data analyzed, it shows that at 45 DAP, the highest number of leaves was found on silver on black plastic (34.29), which was statistically similar to black plastic (32.33) as compared to the control plot, which remained the same at 60 DAP. At 75 DAP, all the mulching material has a higher number of leaves as compared to the control plot. The highest number of leaves was found in silver on black plastic (145.70), which was statistically similar to black plastic (129.95) as compared to the control plot (76.62). Throughout all days of data collection, it was observed that the number of leaves in the plots with plant residues was greater than in the control plots (Table 3). Ruíz-Machuca et al. (2015) discovered similar results, confirming that black and silver plastics are effective in increasing leaf area when compared to bare land. The positive impact of these plastic mulches in enhancing leaf area would increase the rate of photosynthesis, plant yield, and quality.

Plant height

The result of the statistical analysis showed that there was a significant effect of mulching materials on plant height. On evaluating the plant height at different DAPs, the highest plant height was observed in both plastic mulches as compared to the rest of the treatments. At 45, 60, and 75 DAP, the plant height observed in silver on black plastic (43.20 cm, 63.22 cm, and 84.00 cm, respectively) was significantly higher than that of the control plot at 45 DAP, 60 DAP, and 75 DAP (33.04 cm, 48.37 cm, and 61.62 cm, respectively). Similarly, higher plant height was obtained in plots treated with black plastic and plant residues than in control plots. The growth rate was better and huge in all treatments where mulching was applied (Mahmood et al., 2002). The higher soil temperature under plastic mulches leads to an active metabolism in the plants, with an increase in the amount of nutrients absorbed and an enhancement of growth parameters. The enhanced plant height in mulched plants could be attributed to the mulches' improved availability of soil moisture and optimum soil temperature (Joshi et al., 2020). Changes in the plant height of potatoes have been observed when using

Table 3. Number of leaves of potato as influenced by different mulching materials and zinc level at Liwang, Rolpa, 2022

Treatment	Germination Percentage	Number of leaves			Plant height		
		45 DAP	60 DAP	75 DAP	45DAP	60 DAP	75 DAP
Mulching							
Silver on black plastic	94.00[a]	34.29[a]	57.41[a]	145.70[a]	43.20[a]	64.35[a]	87.28[a]
Black plastic	94.67[a]	32.33[a]	50.95[a]	129.95[a]	40.29[ab]	56.71[b]	79.71[b]
Plant Residue	86.00[b]	25.41[b]	36.04[b]	107.12[b]	38.08[b]	53.58[c]	74.42[b]
Control	75.33[c]	23.50[b]	30.58[b]	76.62[c]	33.04[c]	50.20[d]	64.86[c]
SE_m (+̲)	0.49	0.34	0.56	1.38	0.21	0.23	0.43
LSD	5.90***	3.64***	6.70***	16.62***	3.85***	2.82***	5.32***
CV	5.45	11.09	12.45	11.76	5.23	4.05	5.61
Zinc							
4 kg/ha	88.33[a]	29.29[a]	45.10[a]	119.45[a]	40.63[a]	57.08[a]	78.22[a]
0kg/ha	86.67[a]	28.47[a]	42.39[a]	110.25[a]	39.92[a]	55.34[a]	71.67[a]
SE_m (+̲)	0.69	0.46	0.78	1.95	0.30	0.32	0.62
LSD	4.17[ns]	2.78[ns]	4.74[ns]	11.75[ns]	1.84[ns]	1.99[ns]	3.76[ns]
CV	5.45	11.09	12.45	11.76	5.23	4.05	5.61
Grand mean	**87.5**	**28.88**	**43.75**	**114.85**	**40.28**	**55.67**	**76.57**

Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, means with different letters in columns are significantly different at p <0.05 level by DMRT. *Significant at p <0.05 and ** significant at p<0.01 level. ***significant at p<0.001. ns: non-significant.

different mulches, and plastic mulch increased the plant height more than other mulches.

Canopy Diameter

At 45 DAP and 60 DAP, canopy diameter was found to be widest in silver on black plastic (21.06 cm and 29.77 cm, respectively), which was statistically similar with black plastic (19.78 cm and 28.43 cm, respectively) and has a significantly wider canopy diameter as compared to the control plot (17.41 cm and 24.23 cm, respectively). At 75 DAP, the widest canopy diameter was found in silver on black plastic (32.93), which was statistically similar to black plastic (30.91) and plant residue (30.17), and the lowest canopy diameter was found in the control plot (27.18). In all observations, all the mulching materials have shown a wider canopy diameter as compared to the control plot (Table 4).

results were reported by Bari et al. (2001); Sarkar et al. (2018) and Islam et al. (2021).

Tuber Characteristics

The circumference, length, and diameter of potatoes were found to be significantly higher in silver on black plastic (15.35 cm, 6.01 cm, and 4.74 cm, respectively), and the lowest circumference was found in the control plot (12.16 cm , 4.56 cm, and 3.68 cm, respectively). There was no significant difference between plant residue and control plots in case of tuber characteristics (Table 5). Potatoes are sensitive to high soil temperatures and need optimum soil temperatures for tuber initiation and bulking (Dvořák et al., 2012). Silver plastic mulches are better at reflecting PAR (photosynthetically active radiation) than black and white plastic mulches. Such higher reflection of PAR by silver plastic mulches reduces root zone temperature, which creates optimum soil temperature and reduces water loss (Amare & Desta, 2021).

Table 4. Canopy diameter of potato as influenced by different mulching materials and zinc level at Liwang, Rolpa, 2022

Treatment	Canopy Diameter		
	45 DAP	60 DAP	75 DAP
Mulching			
Silver on black plastic	18.77[a]	29.77[a]	32.93[a]
Black plastic	17.43[ab]	28.43[ab]	30.91[a]
Plant Residue	15.44[bc]	26.52[bc]	30.17[a]
Control	13.73[c]	24.23[c]	27.18[b]
SE_m (+)	0.23	0.25	0.22
LSD	2.82**	3.02**	2.69**
CV	13.94	8.97	7.17
Zinc			
4 kg/ha	16.96[a]	27.71[a]	30.44[a]
0kg/ha	15.73[a]	26.77[a]	30.15[a]
SE_m (+)	0.32	0.35	0.31
LSD	1.99[ns]	2.14[ns]	1.90[ns]
CV	13.94	8.97	7.17
Grand mean	**16.34**	**27.24**	**30.30**

Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, means with different letters in columns are significantly different at p <0.05 level by DMRT. *Significant at p <0.05 and ** significant at p<0.01 level. ***significant at p<0.001. ns: non-significant.

Under all observations, germination percentages, number of leaves, plant height, and canopy diameter were found to be higher in plots with 4 kg/ha zinc in comparison to control plots; however, the difference was not significant. Zinc immobility may be the cause of the plant's inability to respond in its early stages. Similar

The circumference, length, and diameter of potatoes were found to be significantly greater in the zinc-treated plot (14 cm, 5.46 cm, and 4.25 cm, respectively) than in the control plot

(13.19 cm, 5.07 cm, and 4.02 cm, respectively). The translocation of assimilates becomes higher in later stages (i.e., in developing tubers) by the application of zinc, which ultimately leads to an increase in tuber size (Sarkar et al., 2018).

Tuber Number

When compared to the control plot, there were more tubers after mulching. A significantly higher number of tubers per plant was found in the silver on black plastic plot (22.16), and the lowest number of tubers per plant was found in the control plot (11.70). As compared to the control plot, the tuber number in plot treated with plant residue was higher.Tuber number was reported to be higher in mulched conditions than in non-mulched conditions because mulching helps to regulate temperature and maintain adequate environmental conditions, which is in accordance with the findings of Sekhon et al. (2020). Application of zinc at a level of 4 kg/ha has shown a significantly higher tuber number (18.39) as compared to the control plot (15.95). Zinc fertilization may have enhanced cytokinin concentration as well as the rate of photosynthesis and respiration, which in turn eliminated apical dominance and resulted in more tubers per plant (Sarkar et al., 2018).

Yield attributed characters

The analysis of interaction effect of mulching and zinc on yield per plant is not significant (Table 6), so we analyze main effects.

A plot with mulching has shown significantly higher tuber weight, yield per plant, and total yield. The highest tuber weight and yield per plant were obtained in silver on black plastic (75.93 g and 465.86 g, respectively), and the lowest tuber weight and yield per plant were recorded in the control plot (39.01 g and 244.82 g, respectively). Similarly, a significantly higher total yield was obtained in silver on black plastic (21.83 t/ha), and the lowest yield was found in the control plot (11.72 t/ha). The yield attributed characters i.e. tuber weight, yield per plant and total yield was higher in black plastic and plant residue as compared to control plots (Table 7). The lower yields in black plastic compared to silver on black plastic may be due to excessive rainfall during the research and higher temperatures during tuberization and tuber growth (Kapoor, 2012). It was also reported that silver and white colored plastic mulches outperformed black colored plastic mulch in tuber yield of potatoes. Yield in plastic mulch might be due to maximum temperature, maximum water retention in the soil, and minimum growth of the weed, which

Table 5. Tuber characteristics of potato plant as influenced by different mulching materials and zinc level at Liwang, Rolpa, 2022

Treatment	Tuber Data			Number of tubers per plant
	Circumference	Length	Diameter	
Mulching				
Silver on black plastic	15.35[a]	6.01[a]	4.74[a]	22.16[a]
Black plastic	13.96[b]	5.55[b]	4.25[b]	18.62[b]
Plant Residue	12.91[c]	4.95[c]	3.87[c]	16.20[c]
Control	12.16[c]	4.56[c]	3.68[c]	11.70[d]
SE_m (+)	0.063	0.028	0.017	0.19
LSD	0.76***	0.34***	0.20***	2.37***
CV	4.72	5.22	4.084	11.15
Zinc				
4 kg/ha	14.00[a]	5.46[a]	4.25[a]	18.39[a]
0kg/ha	13.19[b]	5.07[b]	4.02[b]	15.95[b]
SE_m (+)	0.089	0.039	0.024	0.27
LSD	0.54**	0.24**	0.14**	1.67**
CV	4.55	5.22	4.084	11.15
Grand mean	**13.6**	**5.27**	**4.13**	**17.17**

Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, means with different letters in columns are significantly different at p <0.05 level by DMRT. *Significant at p <0.05 and ** significant at p<0.01 level. ***significant at p<0.001. ns: non-significant.

coincides with the findings of Ahmed et al., (2017). Ruíz-Machuca et al. (2015) also found a significant effect on yield for silver on black, followed by white on black mulching.

The increased tuber yield of potatoes might be attributed to the beneficial effect on tuberization as a result of Zn application (Mondal et al., 2015; Singh et al., 2009).

Table 6. Analysis of variance of yield attributing characters of potato plant as influenced by different mulching materials and zinc level at Liwang, Rolpa, 2022

Source	Yield attributes			
	Df	Tuber Weight	Yield per Plant	Total Yield
Replication	2	83.10	2975*	3.819
Mulch(A)	3	1618.87***	52227***	108.842***
Zinc(B)	1	321.42**	7930**	15.990**
A*B (mulch: zinc)	3	29.71	490	0.133
Error	14	28.93	591	1.403

Note: *Significant at p <0.05, ** significant at p<0.01 level, ***significant at p<0.001, ns: nonsignificant.

Table 7. Yield attributing characters of potato plant as influenced by different mulching materials and zinc level at Liwang, Rolpa, 2022

Treatment	**Yield Attributing Characters**			**Benefit-Cost Ratio**
	Tuber weight (g)	**Yield per Plant (g)**	**Total Yield (t/ha)**	
Mulching				
Silver on black plastic	75.93ᵃ	465.86ᵃ	21.83ᵃ	3.18ᵃ
Black plastic	60.51ᵇ	376.48ᵇ	18.27ᵇ	2.28ᵇ
Plant Residue	45.73ᶜ	319.40ᶜ	15.71ᶜ	1.75ᶜ
Control	39.01ᵈ	244.82ᵈ	11.72ᵈ	1.13ᵈ
SE_m (+̲)	0.54	2.48	0.12	0.019
LSD	6.66***	30.10***	1.46***	0.23***
CV	9.72	6.91	7.01	9.16
Zinc				
4 kg/ha	58.95ᵃ	369.82ᵃ	17.70ᵃ	2.26ᵃ
0kg/ha	51.63ᵇ	333.46ᵇ	15.66ᵇ	1.91ᵇ
SE_m (+̲)	0.77	3.50	0.17	0.027
LSD	4.70**	21.28**	1.03**	0.16***
CV	9.72	6.91	7.01	9.16
Grand mean	**55.29**	**351.64**	**16.88**	**2.09**

Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, means with different letters in columns are significantly different at P <0.05 level by DMRT. *Significant at P <0.05 and ** significant at P<0.01 level. ***significant at P<0.001. ns: non-significant.

Similarly, application of zinc at a level of 4 kg/ha has shown significantly higher tuber weight (58.95 g), yield per plant (369.82 g), and total yield (17.70 t/ha) as compared to the control plot (51.63 g, 333.46 g, and 15.66 t/ha, respectively). In an earlier study, Kumar et al. (2008a) meticulously recorded the favorable effect of ZnSO4 on crop development, increased synthesis, and food material translocation to developing tubers. Later research revealed that using Zn aided in increasing the average weight of individual tubers from small to medium and medium to large size (Kumar et al., 2008b).

Benefit-Cost Ratio

The highest B:C ratio was found in plots with silver on black plastic (3.18), followed by black plastic (2.28), plant residue (1.75), and the lowest on a control plot (1.13). Similarly, the B:C ratio was found higher in plots with a 4 kg/ha level of zinc (2.26) than control plots (1.91). Chaudhary et al. (2022) also reported the highest gross return and a promising B:C ratio of 2.75 on silver on black plastic mulch conditions in comparison to other mulch conditions, which is in accordance with the findings of this study.

Conclusion

Mulching activities have a positive impact on microclimates and contribute to the maintenance of better growing environments, which is imperative for increasing crop productivity. The use of appropriate mulching practices is a necessary precursor to addressing the irrigation and weed infestation problems in potato production. Zinc application further enhances potato tuber quantity and quality. The study concluded that mulching was effective in enhancing the vegetative growth as well as the overall yield of potatoes. Among the various mulching materials tested, silver on black plastic and black plastic were the most effective in increasing tuber yield. The interaction effect of mulching and zinc on growth and yield parameters was found to be non-significant. Despite having a non-significant effect, it leaned towards the positive effect of using them together. No such declination was seen in the yield or any other parameters. Consequently, to maximize profit, it would be advantageous to use silver on black plastic mulch as the best mulching material and 4 kg of zinc per hectare to augment the yield. Furthermore, as the research was carried out in only one season at a particular location, future studies should emphasize the investigation of different mulching materials in different agro-ecological zones for validation.

Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of Interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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