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Growth and Yield of Summer Squash (*Cucurbita pepo* var. *sunny house*) in Response to Organic and Inorganic Mulching Materials at Rampur, Chitwan

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ABSTRACT

Mulching, a widely employed agricultural practice, has been recognized for its influence on soil moisture retention, temperature regulation, and weed suppression, thereby improving growth and yield of crops. An experiment was conducted to study the effect of mulching materials on growth and yield attributes of summer squash under water constraint condition during March to May 2023 in Chitwan, Nepal. The experiment was laid in single factor Randomized Complete Block Design (RCBD) with four different mulches (rice straw, wheat straw, rice husk and silver on black plastic mulch 30 microns) and control replicated 4 times. All the Plant growth parameters, including plant height, number of leaves per plant and plant spread, were highest in silver plastic mulch and the poorest in the un-mulched plots. Mulching also significantly influenced floral characters, with plastic mulch demonstrating superiority in traits such as days to flowering, number of flowers per plant, and sex ratio compared to organic mulches and the control. Fruit length, diameter, and weight exhibited the highest values under plastic mulch and the lowest values under the control, while all organic mulches showed similar results. The highest yield of 41.44 Mt ha^{-1} was achieved with silver plastic mulch, highlighting its effectiveness in enhancing crop productivity, while the lowest yield of 11.77 Mt ha^{-1} was recorded in the control plots. Despite its higher cost, silver pastic mulch exhibited highest net return and benefit-cost ratio. Rice husk mulch, with the second highest benefit-cost ratio and relatively low cost of production, emerged as promising alternative. Although mulching did not notably affect the soil pH, the varying soil organic matter percentages were observed, with the highest on rice straw mulch and the lowest on silver plastic mulch. The study suggests that while plastic mulch can significantly boost productivity during water scarcity, rice husk mulch offers a cost-effective alternative with substantial economic benefit.

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Introduction

Summer squash, a member of the *Cucurbita pepo* L. species, is a versatile and economically important vegetable crop with a rich history and diverse horticultural groups (Paris 1996). Among these, the zucchini cultivar-group is particularly significant (Lust & Paris, 2016). The health benefits of summer squash, including its bioactive compounds and nutritional composition, are widely recognized (Tadros et al., 2023; Díaz et al., 2020). Additionally, the fruit of the summer squash is rich in fiber and vitamins and contains moderate amounts of mineral salts (Abdein, 2016).

Summer squash cultivation is quite popular in Nepal. However, the productivity of summer squash in Nepal is 14.3 Mt/ha, which is lower than the global average of 15.83 Mt/ha (MoALD, 2021/2022; FAO STAT 2021). In Nepal, summer squash is cultivated during the spring season, a particularly dry period (Regmi et al., 2021; Shrestha et al., 2021). Any degree of water stress can adversely affect the growth and yield of crops (El-Monayeri et al., 1984). Drought stress significantly decreases gas exchange parameters and physiological properties (Ors et al., 2016). Water stress in summer squash, as demonstrated by Ors et al. (2016) and Doklega et al. (2022), significantly reduces growth and yield parameters, including leaf chlorophyll reading values, leaf relative water content, stomatal conductance, photosynthetic rate, transpiration rate, fresh weight, and dry weight.

Research by Mahmood et al. (2014) found that mulching practices are highly effective in conserving soil moisture, leading to increased plant growth. The use of various mulching materials has significantly improved the growth and yield of summer squash (Kumar & Sharma, 2018). Mulching involves spreading organic or inorganic materials on the soil surface to create a more favorable environment for plant growth and development (Bobby et al., 2017). Locally sourced organic mulching materials, which are biodegradable, play a significant role in regulating temperature and water retention while also promoting higher levels of biological activity (Kwambe et al., 2015). Kumar & Sharma (2018) observed that the type of mulch used, the variety of summer squash, and their interaction had a significant impact on the total soluble solids (TSS) content in the fruit. Mahadeen (2014) found that mulching can lead to higher soil moisture content, positively affecting vegetative growth and yield by stimulating root growth through increased soil temperature and moisture. Sarmah et al. (2022) specifically noted the benefits of reduced weed problems and increased soil temperature due to mulching.

Youssef et al. (2021) found that organic mulches, including rice straw, positively impact soil properties, growth, and yield of squash plants. Barreda et al. (2023) observed that rice straw mulch effectively controls weeds and improves soil fertility, leading to increased grain yield. Parhizkar et al. (2021) further demonstrated the effectiveness of rice straw mulch in reducing surface runoff and soil loss, particularly at higher application rates. Paul et al. (2020) reported that straw mulching improves water use efficiency and soil water content, resulting in increased yields. Zhang et al. (2011) showed that mulching could reduce canopy temperature, increase relative humidity, and enhance the photosynthetic rate, all of which contribute to higher yields.

Noor et al. (2020) found that the increase in yield is attributed to the moderating influence of wheat straw mulch on soil temperature and its ability to enhance moisture retention. Peng et al. (2015) demonstrated that wheat straw mulch can increase soil water content and water use efficiency, leading to a substantial increase in wheat yield. Additionally, Aziz et al. (2022) found that wheat straw mulch can suppress weeds and conserve soil moisture, resulting in improved wheat growth and yield.

The application of rice husk mulch has been shown to improve germination percentage, yield, and the economics of pea production (Abonmai et al., 2023). Furthermore, the use of rice husk charcoal, a byproduct of rice husk, increased plant growth and soil carbon content in rice fields, although it did not significantly affect grain yield (Koyama & Hayashi, 2017). Rice husk mulch creates a favorable microclimate by reducing canopy temperature and increasing relative humidity, which enhances the photosynthetic rate and yield components (Zhang et al., 2011). It also conserves soil moisture, crucial for plant growth and development (Rahman & Khan, 2001). Additionally, rice husk mulch can improve soil physicochemical properties, such as reducing soil acidity and increasing water content, further supporting plant growth and yield (Mishra et al., 2017).

Plastic mulching material is widely used due to its convenient processability, exceptional chemical resistance, durability, flexibility, and absence of harmful substances and odors (Lamont, 2017). Ahirwar et al. (2023) found that the reflective nature of silver mulch enhances photosynthesis and promotes uniform plant growth, leading to increased grain yield. This improvement is attributed to silver mulch's ability to maintain optimal root zone temperature, reduce heat stress, and suppress weed growth. Plastic mulches impede evaporation and moderate both soil temperature and moisture, promoting better root development and nutrient absorption by plants, resulting in enhanced growth (Kumar & Sharma, 2018). The elevated soil temperature from black plastic mulch creates a favorable microclimate for plant growth, enhancing photosynthesis and other metabolic activities, which in turn promotes earlier growth and development, leading to accelerated flowering and fruiting (Chaurasia et al., 2020). Consequently, plants grow better, absorb more nutrients, and produce a higher yield earlier than usual (Yaghi et al., 2013). Additionally, black polythene mulch acts as a physical barrier, preventing light from reaching the soil, which is essential for weed seed germination and growth, thereby minimizing weed density (Bobby et al., 2017).

It is evident that with the right microclimate surrounding the crop and soil through mulching, it is possible to achieve moisture conservation, improved soil structure, reduced incidence of pests and diseases, and better crop growth and yield. Therefore, with the objective of identifying the most beneficial and cost-effective mulching method and understanding the effects of different types of mulching materials on soil properties such as soil pH and organic matter, this experiment was conducted in the Horticulture field of Agriculture and Forestry University, Rampur, Bharatpur, Chitwan.

Materials and Methodology

Experimental Site

The experiment was conducted at Rampur, Chitwan district, at an altitude of 208 meters above sea level, during the spring-summer season from March to May 2020. The geographical coordinates of the research site are 27°39'00.9"N latitude and 84°21'09.8"E longitude (GPS). The research field was at located at Horticulture Research Field of Agriculture and Forestry University.

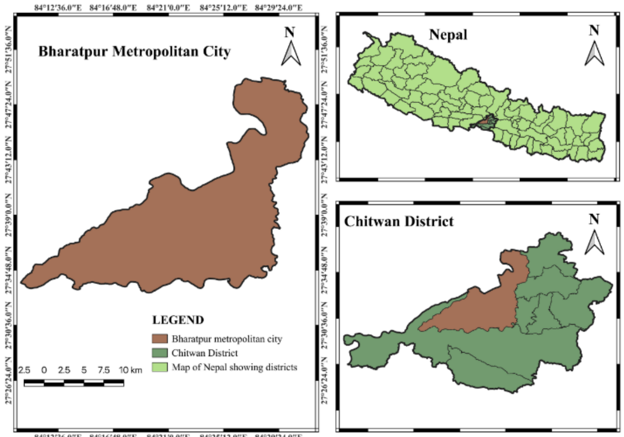

Figure 1. Map showing research area

Climatic Condition and Soil Characteristics of The Experimental Site

The climatic data was taken from the meteorological station of National Maize Research Program, Rampur, Chitwan. Both maximum and minimum temperatures were in an increasing pattern from February to May (Figure 2). There was no precipitation in February and March. April and May received 24.3 mm and 43.9 mm of rainfall, respectively. The highest average temperature of 34°C was recorded in May. There was no precipitation in February and March. April and May received 24.3 mm and 43.9 mm of rainfall, respectively. Table 1 shows the soil characteristics of the study site before the experiment.

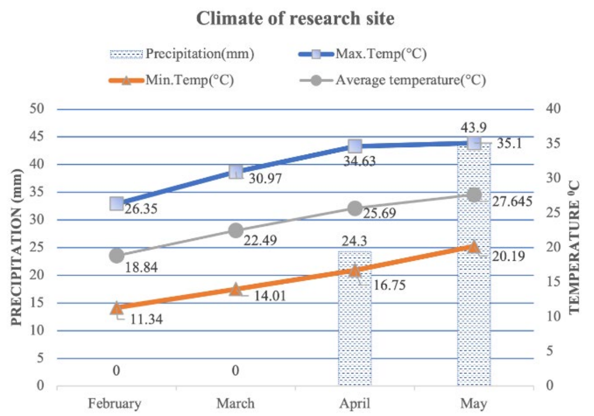

Figure 2. Cardinal Temperature and rainfall distribution in research area in 2023

Table 1. Description of Soil Status of the experimental field

Characteristics	Value
Soil depth (cm)	15-20 cm
Soil texture	Sandy-loam
Organic Matter (%)	2.1
pH	7.1
N (%)	0.32
P_2O_5 (kg/ha)	37.20
K_2O (kg/ha)	249.6

Source: Soil and Fertilizer testing laboratory, Hetauda, 2023

Experimental Design

The experiment was laid out in Randomized Complete Block Design using five treatments, which were replicated four times. The treatments were T1: control (no mulching material), T2: rice straw, T3: wheat straw, T4: rice husk, and T5: silver on black plastic mulch (30 microns).

Sunny house variety of summer squash was used for this experiment. The total plot area of the experiment was 494.7 m^2 , with twenty plots each with an area of 16.2 m^2 (4.5*3.6 m^2). There was a 1 m distance between replications and 0.5 m distance between each plot within a replication. The spacing of the plants inside each plot was 90cm*90cm (PP*RR). There were four rows with five plants inside each plot, thereby accommodating 20 plants in each plot.

The seeds were sown in polybags under controlled protected conditions. The growing media used was prepared by using well rotten FYM and garden soil in a ratio of 2:1. The media was treated with the fungicide Saaf (Carbendazim 12% + Mancozeb 63% WP). A single seed was sown in each polybag. Regular watering was carried out as required. After complete germination of the seed, seedlings bearing true leaves at 2–3 weeks of age were transplanted. The main field was ploughed twice, followed by planking to attain the good tilth required for planting. 5.4 kg FYM was applied per plot, and the recommended dose of N: P: K @ 12:9:3 kg/ropani was applied in the form of urea, DAP and MoP respectively (MoALD, 2021). The seedlings were transplanted at the required spacing of 90cm * 90cm. The mulching material were added a day prior to transplanting and at the rate of 10 kg per plot (MoALD, 2021). Other intercultural operations such as weeding, pest, and disease management were uniformly carried out across the experimental plots. With respect to irrigation, it was carried out at two-week interval from the date of transplanting in the main field. Harvesting was done manually at the appropriate physiological maturity stage when the fruits were still green.

Observation Taken

Plant growth parameters

- *Plant height:* It was measured from ground level to the tip of the main shoot with the help of scale at 20 days intervals (20,40 and 60 days after transplanting) and the average was calculated. The plant height was expressed in centimeters.
- *Number of leaves per plant:* The number of green, photosynthetically active leaves excluding senescent and emerging leaves per plant were counted at 20 days intervals (20,40 and 80 days after transplanting) and average were calculated.
- *Plant Spread:* Plant spread was measured at 20-day interval (20,40, 60 DAT) in both North-South and East-West directions. The maximum growth in each direction was recorded and the average plant spread was calculated.

Flowering Parameters

- *Days to opening of first male and first female flower:* The number of days from transplanting to the opening of the first male flower and first female flower was recorded.
- *Numbers of male and female flowers per plant:* Number of male and female flowers per plants was recorded in 3-4 days interval after initiation of flowering till the end of harvesting season from the same sample plants. Flowers that were either open or had bloomed since the last sampling day were the only ones counted. Petals were removed during each sampling period to ensure accurate counts in subsequent intervals. Plants with any abnormalities were excluded from the data analysis.
- *Sex ratio:* Sex ratio was calculated by dividing the total numbers of the male flowers by the total number of female flowers.

Yield parameters

- *Days to first harvest:* The number of days taken from transplanting to the first harvest was recorded and the average was calculated.
- *Number of fruits per plant:* The total number of fruits obtained from the sample plants from each harvest was divided by 5 to obtain the data.
- *Fruit length:* The length of each fruit harvested from the sample plant was measured individually from base of calyx to the tip and average was calculated.

- *Fruit diameter:* The diameter of each fruit harvested from the sample plant was measured individually at the widest point using vernier caliper and average was calculated.
- *Fruit weight:* The fruit weight was recorded by dividing the total weight of fruits harvested from the sample plants by the number of fruits in each harvest and average was calculated.
- *Productivity:* The net plot yield of the sample plants from each plot was calculated individually, averaged and converted to Mt/ha.

Soil Sampling and Analysis

After the final data recording the research field was left for 1.5 months. After that soil sampling was carried out using screw auger, tube auger and spade and the sample from the top 20 cm was taken from each of the plots. For the analysis or soil organic matter, the samples were subjected to wet digestion using 1 N Potassium Dichromate ($K_2Cr_2O_7$) and 98% concentrated sulphuric acid and titrated against 0.5 N ferrous ammonium sulphate as per the protocols given by (Walkley & Black, 1934). Soil pH was determined at 1:2.5 soil water ratio using pH meter (Cottenie et. al., 1982).

Economic Analysis

The costs incurred during the production of summer squash were both fixed (land lease) and variable (seed, nursery preparation, fertilizers, field preparation, intercultural activities, etc.). Based on data obtained from field trials, the gross return (GR), net return (NR), and benefit-cost (BC) ratios were computed. The selling price of summer squash was set as per the market price during the harvesting period. Gross return (Eq. 1) was calculated as the total return generated before deducting cultivation-related costs, whereas net return (Eq. 2) was calculated as the total return generated after deducting all cultivation-related costs from the gross return. Net return was divided by total production costs to determine the benefit-cost ratio (Eq .3).

Gross returns = Total marketable yield × Selling price of summer squash (Eq. 1)

Net returns = Gross returns – Total cost of production (Eq. 2)

Benefit: Cost Ratio (B: C) = Gross return/Total cost of production (Eq. 3)

Data Analysis

Recorded data was systematically arranged based on various observed parameters. Data entry was done in MS Excel following standard format then data was subjected to one way Analysis of variance (ANOVA) using R Studio. Duncun's Multiple Range Test (DMRT) test was used for mean separation at 5% level of significance.

Results

Plant Growth Parameters

Mulching materials significantly influenced plant height at all stages of observation (Table 2). Silver plastic mulch exhibited the highest plant height at all stages of observation, while the lowest plant height was observed under control. After silver plastic mulching, wheat straw mulch, rice straw mulch, and rice husk mulch resulted in higher plant heights at 20, 40, and 60 DAT, respectively.

The number of leaves per plant was significantly influenced by different mulching materials (Table 3). The maximum number of leaves per plant was observed under silver plastic mulch, which was statistically similar to rice straw mulch and wheat straw mulch at 20 and 60 DAT, respectively. In contrast, the lowest number of leaves per plant was reported under the control condition. After silver plastic mulching, a higher number of leaves were observed under wheat straw mulch at all stages of observation.

Table 2. Effect of different mulching materials on plant height of summer squash.

Treatments	Plant height (cm)		
	At 20 DAT	At 40 DAT	At 60 DAT (cm)
Control	15.19^{c}	19.93^{c}	36.17^{d}
Rice Straw mulch	18.00^{b}	27.35^{b}	43.15^{bc}
Wheat Straw Mulch	18.32^{b}	22.86^{c}	38.20^{cd}
Rice Husk mulch	18.15^{b}	23.23^{c}	44.65^{b}
Silver on black plastic mulch	20.52^{a}	31.025^{a}	51.55^{a}
LSD (0.05)	1.80	3.30	5.63
SEM (±)	0.26	0.48	0.81
F-probability	<0.001	<0.001	<0.001
CV %	6.50	8.62	8.56

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEM: Standard Error of Mean, CV: Coefficient of Variation, DAT: Days after transplanting.

Table 3. Effect of different mulching materials on number of leaves per plant of summer squash.

Treatment	Number of leaves per plant		
	20 DAT	40 DAT	60 DAT
Control	7.90^{c}	19.30^{c}	28.30^{b}
Rice Straw mulch	8.92^{ab}	21.15^{bc}	30.55^{b}
Wheat Straw Mulch	10.15^{bc}	24.65^{b}	34.05^{ab}
Rice Husk mulch	8.62^{bc}	19.9^{bc}	28.70^{b}
Silver on black plastic mulch	11.05^{a}	28.72^{a}	38.00^{a}
LSD (0.05)	1.95	3.60	6.04
SEM (±)	0.28	0.52	0.87
F-probability	<0.001	<0.001	<0.05
CV %	13.60	10.28	12.29

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEM: Standard Error of Mean, CV: Coefficient of Variation, DAT: Days after transplanting

Table 4. Effect of different mulching materials on plant spread of summer squash squash.

Treatment	Plant Spread (cm)		
	20 DAT	40 DAT	60 DAT
Control	56.55[c]	100.37[c]	106.45[c]
Rice Straw mulch	65.77[b]	122.88[b]	127.73[b]
Wheat Straw Mulch	63.32[b]	115.50[b]	121.57[b]
Rice Husk mulch	63.97[b]	122.25[b]	128.20[b]
Silver on black plastic mulch	74.30[a]	135.30[a]	145.05[a]
LSD (0.05)	5.72	11.44	14.35
SEm (±)	0.83	1.66	2.08
F-probability	<0.001	<0.001	<0.001
CV %	5.73	6.23	7.40

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEM: Standard Error of Mean, CV: Coefficient of Variation, DAT: Days after transplanting

Table 5. Effect of different mulching materials on floral characteristics of summer squash.

Treatment	Days to 1st male flower (DAT)	Days to 1st female flower (DAT)	Total no. of male flowers per plant	Total no. of female flowers per plant	Sex ratio
Control	25.30[ab]	30.95[a]	7.12[a]	2.625[d]	3.13[a]
Rice Straw mulch	23.35[c]	26.20[bc]	5.67[b]	2.975[cd]	2.03[b]
Wheat Straw Mulch	26.05[a]	28.05[ab]	6.5[a]	4.10[ab]	1.74[b]
Rice Husk mulch	24.20[bc]	26.10[bc]	5.7[b]	3.50[bc]	1.77[b]
Silver on black plastic mulch	22.90[c]	23.35[c]	5.67[b]	4.75[a]	1.32[c]
LSD (0.05)	1.51	3.63	0.63	0.72	0.41
SEm (±)	0.22	0.527	0.09	0.10	0.06
F-probability	<0.01	<0.01	<0.001	<0.001	<0.001
CV %	4.02	8.76	6.72	13.16	13.49

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEM: Standard Error of Mean, CV: Coefficient of Variation, DAT: Days after transplanting

Table 6. Effect of different mulching materials on yield and yield parameters of summer squash.

Treatment	Days to 1st picking (DAT)	Average fruit diameter (mm)	Average fruit length (cm)	Average fruit weight (kg)	Productivity (mt/ha)
Control	41.85[a]	59.24[c]	26.36[c]	0.49[C]	11.77[c]
Rice Straw mulch	34.45[bc]	63.89[b]	31.67[b]	0.76[ab]	25.03[b]
Wheat Straw Mulch	36.90[b]	62.88[b]	31.02[b]	0.66[b]	24.21[b]
Rice Husk mulch	33.95[bc]	63.45[b]	32.09[b]	0.70[b]	23.12[b]
Silver on black plastic mulch	31.10[c]	66.84[a]	34.43[a]	0.81[a]	41.44[a]
LSD (0.05)	4.17	2.42	2.02	0.09	8.70
SEm (±)	0.605	0.35	0.29	0.01	1.263
F-probability	<0.01	<0.001	<0.001	<0.001	<0.001
CV %	7.59	2.48	4.22	9.35	22.49

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEM: Standard Error of Mean, CV: Coefficient of Variation, DAT: Days after transplanting

Table 4 shows the effect of different mulching materials on the plant spread. The maximum plant spread was observed under silver plastic mulching at stages of observation, while the minimum plant spread was reported under the control plot. After silver plastic mulching, rice straw mulching resulted in a higher plant spread at 20 and 40 DAT, while rice husk straw resulted in a higher plant spread at 60 DAT.

Flowering Parameters

Mulching material had a significant effect on the floral characteristics of summer squash (Table 5). The fastest day to the first male flower was obtained under silver plastic mulch, which was statistically similar to rice straw mulch. Wheat straw mulch was the latest on days to the first female flower, which was statistically similar to no mulching. Similarly, plastic mulching was the fastest for the first pistillate flower, followed by rice husk mulch, which was statistically similar to rice straw mulch. Control was late among all treatments. Control produced the highest number of male flowers per plant, which was statistically similar to wheat straw mulch. Other treatments had a statistically similar number of male flowers per plant. In contrast, plastic mulch condition resulted in maximum number of female flowers per plant. The highest sex ratio was observed in no mulching, and plastic mulch showed the lowest sex ratio.

Yield and Yield Parameters

Mulching material had a significant effect on the yield and yield parameters of summer squash (Table 6). The earliest days to first picking was observed in silver plastic mulch (31.10) followed by rice husk mulch (33.95), rice straw mulch (34.45) and wheat straw mulch (36.90). In contrast, the control resulted in the maximum number of days to reach first harvesting (41.85). Fruit diameter, fruit length, and fruit weight were observed to be highest in silver plastic mulch and lowest in no control. Other treatments had statistically similar average fruit diameter, length, and weight, with rice straw mulching exhibiting higher fruit diameter and fruit weight and rice husk mulch, resulting in longer fruit length. Productivity values varied with silver plastic mulch (41.44 mt/ha) showing the highest, followed by rice straw mulch (25.03 mt/ha), wheat straw mulch (24.21 mt/ha), rice husk mulch (23.12 mt/ha), and control (11.76 mt/ha). Other treatments showed statistically similar productivity (Table 6).

Soil Organic Matter and Soil pH

There was significant variation in the soil organic matter percentage in response to various mulching materials (Table 7). The highest soil organic matter percentage was observed in rice straw mulch (3.31%), followed by rice husk mulch (2.74%), wheat straw mulch (2.71%), and the control condition (2.18%). Silver plastic mulch recorded the lowest organic matter percentage (1.24%). However, there was no significant difference in soil pH in response to different mulching materials.

Economic Analysis

The economic analysis of summer squash production was carried out in two sections. In the first section, the general cost of cultivation for summer squash was calculated (Table 8) that excluded the cost of mulching materials, and later on, the total cost of cultivation was calculated by adding the general cost of cultivation and the cost of mulching materials according to treatments. In the second section, the B:C ratio concerning the treatments was carried out (Table 9). The rate per unit of all the input is based upon the perception of the farmers and the local rate that exists in the Bharatpur area, and the price of summer squash, fixed at NRs 20 per kg, is based on the wholesale selling price in the Khestrapur vegetable market in Chitwan.

Gross return with the use of rice straw mulch, wheat straw mulch, rice husk mulch, and silver plastic was increased by 112.65%, 105.7%, 96.43% , and 252.08%, respectively, compared with control (Table 9).

Similarly, the net return with the use of rice straw mulch, wheat straw mulch, rice husk mulch, and silver plastic increased by 1467.08%, 1564.31%, 1515.7%, and 3438.27%, respectively, compared with control (Table 9).

Highest benefit to cost ratio was found in silver plastic mulch followed by rice husk mulch, wheat straw mulch and rice straw mulch control being the lowest (Table 9).

Table 7. Effect of mulching materials on Soil pH and Organic matter.

Treatment	Soil organic matter (%)	Soil pH
Control	2.18^{d}	6.86
Rice Straw mulch	3.31^{a}	6.89
Wheat Straw Mulch	2.71^{c}	6.91
Rice Husk mulch	2.74^{b}	6.88
Silver on black plastic mulch	1.24^{e}	6.82
LSD (0.05)	0.02	NS
SEm (±)	0.003	0.026
F-probability	<0.001	0.83
CV %	0.66	1.69

NOTE: Means followed by the same letter in a column are not significantly different by DMRT at a 5% level of significance. LSD: Least Significant difference, SEm: Standard Error of Mean, CV: Coefficient of Variation

Table 8. Cost of cultivation for summer squash (NRs ha^{-1}).

S.N.	Particulars	Unit	Rate per unit	Quantity used	Cost (NRsha^{-1})
1	Land preparation by tractor	hour	1500	10	15000
2	Land Rent				32000
	Seeds	kg	23000	1.961	45080
4	Nursery raising	Lumpsum			15450
5	Fertilizer (Synthetic)	kg			
*	Urea		25	235.29	5882.25
*	DAP		50	176.47	8823.50
*	MOP		50	58.82	2941
6	Fertilizer (Organic)	kg	3	29411.76	88235.28
7	Fruit fly traps		50	40	2000
8	Harvesting labor	man hour	150	40	6000
				General Cost of Cultivation	221412.03
	Mulching materials				
1	Silver on black plastic mulch	meter	13.5	8333	112495.5
2	Wheat straw	kg	5	6000	30000
3	Rice straw	kg	10	6000	60000
4	Rice husk	kg	5	3000	15000

Table 9. Benefit Cost Ratio Analysis

Treatments	Cost of cultivation (NRs ha^{-1})	Productivity (kg/ha)	Average price per kg	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B:C ratio
Control	221413	11770	20	235400	13987	1.07
Rice straw	281413	25030	20	500600	219187	1.78
Wheat Straw	251413	24210	20	484200	232787	1.93
Rice husk	236413	23120	20	462400	225987	1.96
Silver on black plastic mulch	333903	41440	20	828800	494897	2.49

Discussion

The increased performance of summer squash plants under mulching conditions can be attributed to soil moisture conservation, lower evaporation, a lower weed population, and increased soil temperature. The mulching materials act as a barrier to evaporating moisture vapor, cool the soil surface, and reduce the impact of sunlight energy (Jabran, 2019). McMillen (2013) reported that mulching material up to 5 cm can reduce surface evaporation by 40% compared to bare soil. Similarly, mulching materials cover the soil surface, creating a physical barrier that shades the emerging weed and hinders their access to sunlight, which is necessary for their germination and growth(Hussain & Luqman, 2022). This reduces the competition for essential resources such as sunlight, nutrients, and water, which leads to better plant growth. Plastic mulches absorb the incoming solar radiation and transfer a considerable part of it to the soil, increasing the soil temperature. This increased temperature can lead to better nutrient and water absorption by plants by influencing soil physiochemical properties and microbial activities. Elevated temperatures can increase the availability of essential nutrients and organic carbon (Islam et al., 2020) as well as stimulate microbial activity, accelerate the decomposition process, and facilitate nutrient cycling (Auwal et al., 2021; Dai et al., 2020).

The highest plant height was observed under silver plastic mulching at all stages of observation, and the lowest under control (Table 1). This is in line with the study conducted by Ekinci & Dursun (2009) who reported the highest plant height under plastic mulch in melon (*Cucumis melo L.*). Similar results were observed by (Hallidri, 2000) on cucumber and (Chaurasia et al., 2020) on summer squash. The use of plastic mulch inhibits evaporation, moderates soil temperature, and maintains favorable moisture conditions, thereby promoting improved root development and nutrient absorption, ultimately enhancing overall plant growth (D. Kumar & Sharma, 2018).

Similarly, silver plastic mulch resulted in the maximum number of leaves per plant and was statistically similar to rice straw mulch and wheat straw mulch at 20 and 60 DAT, respectively (Table 2). This finding is consistent with findings (Rajablariani et al., 2012) who reported the maximum number of leaves per plant in mulched soil compared to bare soil in tomatoes. Similar results were obtained by (Bhatt et al., 2011) on summer squash and by Sil et al. (2022) on cauliflower. The increase in leaves per plant is directly linked to the absorption of solar radiation by mulches, especially plastic mulch, and the transfer of a significant portion of it to the soil, thereby elevating temperatures to levels conducive to increased leaf formation (Radhika Regmi et al., 2021).

In addition, the maximum plant spread was observed under silver plastic mulch and the lowest under the control condition (Table 3). Similar findings were reported by (Bhatt et al., 2011) and (Kumar et al., 2012) in summer squash and strawberry, respectively. Mulching helps in maintaining soil moisture, temperature, and nutrient level, which are essential for optimal plant spread (Sharma & Menon, 2020).

Furthermore, the lowest number of days to first staminate and pistillate flowers was observed under the plastic mulch condition, while the highest number was reported under the control condition(Table 4). Bhatt et al. (2011) observed earliness in flowering in plastic mulches, followed by organic mulches. He concluded that higher soil temperature under plastic mulch improves the plant microclimate, leading to early growth and development, which advanced flowering. Similarly, control resulted in the maximum number of male flowers per plant, while plastic mulch resulted in the highest number of female flowers per plant. The highest sex ratio was observed in no mulching, and plastic mulch showed the lowest sex ratio (Table 4). Karki et al. (2020), in a similar study, reported the highest number of female flowers per plant under plastic mulch conditions and the lowest under control.

Enhanced fruit dimensions, including length and diameter, as well as increased average fruit weight, were observed under silver plastic mulch. This observation aligns with the findings of Reddy et al. (2022) and Hossen et al. (2023), who reported superior fruit length and diameter under plastic mulch conditions. Additionally, Bhatt et al. (2011) documented a greater average fruit weight under plastic mulch. Plastic mulch resulted in the highest yield (41.44 mt ha-1) while control resulted in the lowest yield (11.77 mt ha-1) (Table 5). Similar results were reported by Chaudhary et al. (2023), Rajablariani et al. (2012),and Chaurasia et al. (2020) in okra, tomato, and summer squash, where the highest yield was obtained under plastic mulch conditions. The better dimension and weight of fruit and yield under plastic mulch can be attributed to the improved moisture retention, soil temperature regulation, increased nutrient availability, and effective weed suppression (Han et al., 2021; Samphire et al., 2023).

Organic mulching increased soil organic matter%, with the highest under rice straw mulch while the lowest was reported under plastic mulching(Table 6). This is in line with the findings of Bajorienė et al. (2013) where a higher content of SOC (soil organic carbon) was established in all mulched experimental plots compared with the unmulched plots. Zhai et al. (2008) reported that the concentration of soil organic matter, at a soil depth of 0–20 cm, was considerably higher under the mulching treatment as compared to the control. Similarly, Kumar (2014) observed the highest soil organic carbon in farmyard manure, followed by brankad (*Adhotada vassica*), maize straw, bajra straw, and palah leaves, and the lowest without mulch. Samphire et al. (2023) reported an increased organic matter decay rate and a higher soil CO2 efflux rate under plastic film mulching and suggested that plastic film mulching can accelerate the decomposition rate of organic matter content. This might explain the lower soil OM content in plastic mulch compared to the control.

Despite the higher production costs associated with silver plastic mulch, it demonstrated the highest net return (NRs/ha) and a benefit-cost ratio of 2.49. This result is consistent with the findings of Thapliyal et al. (2014) and Bhatt et al. (2011), who also reported higher net returns and benefit-cost ratios under plastic mulch conditions. Regmi et al. (2021) similarly observed higher net returns and benefit-cost ratios with silver plastic mulch, further supporting our findings. Conversely, rice husk mulch, as an organic alternative, offers a more economical cost of production and the highest benefit-cost ratio (1.96) among the remaining treatments.

Conclusion

Overall, this study presents mulching as a suitable and efficient agricultural practice that can enhance the growth and yield performance of summer squash. Silver plastic mulch was superior to other mulching materials in promoting plant height, number of leaves, plant spread, and floral characteristics. Notably, silver plastic mulch resulted in the highest yield and productivity, followed by rice straw mulch, wheat straw mulch, and rice husk mulch. The increased performance under mulching conditions can be attributed to soil moisture conservation, reduced evaporation, lower weed population, and soil temperature regulation. Organic mulches, such as rice straw, significantly increased soil organic matter percentage, indicating their potential to enhance soil health. However, plastic mulching recorded the lowest organic matter percentage, likely due to accelerated decomposition rates. Despite its higher expense, silver plastic mulch yielded the greatest gross and net returns and a favorable benefit-cost ratio, highlighting its economic viability. Rice husk mulch emerges as a notable alternative as it offers a lower production cost and the second highest benefit-cost ratio among the tested treatments. Additionally, as an organic option, rice husk mulch can also enhance soil organic matter and contributes positively to soil health. Thus, this study emphasizes the importance of selecting the appropriate mulching material to maximize plant growth, yield, and economic returns.

Limitations of the study and suggestions for future study

This study was conducted on a single soil type, focusing only on soil organic matter and pH. Hence, it is recommended that future investigations should analyze impacts of diverse kinds of mulching materials on various soil types as well as climatic conditions for long times. The results would be more generalized if they involved experiments done at different sites and during multiple seasons. Moreover, the economic analysis carried out in this research was short-term. To examine how it affects the economy over a longer period would require an extensive approach that involves both short-term and long-term cost-benefits analysis. This will help to provide some clarity on whether or not the use of mulching materials are economically viable in long run. The scope of tested mulching materials was narrow. Further inquiries are needed to encompass a wider array of organic and inorganic mulches that better inform their efficiency across crops and conditions. Similarly, a wider range of such properties like microbial activity, soil structure etc., should be evaluated alongside environmental hazards related to biodegradable plastics. Investigating how different mulching materials interact with various irrigation practices is another crucial area for future research. This would provide valuable insights into the water efficiency of mulching materials, particularly in regions where water is scarce.

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