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Effect of different mulching materials on growth and yield of broccoli (*Brassica oleracea* var. *italica*)

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ABSTRACT

A field experiment was conducted at Purkot daha, Gulmi, Nepal from October 2020 to March 2021 with an objective to assess the suitability of locally available mulching materials compared to the black plastic mulch and no mulch on growth and yield of broccoli (*Brassica oleracea* var. *italica*). The field was laid out in Randomized Complete Block Design (RCBD) with four replications and five treatments *viz.*, M0= Maize stalk, M1= twigs and leaves of needlewood tree, M2= twigs and leaves of eupatory, M3= Black plastic mulch, and M4= No mulch. The growth parameters were recorded at various days after transplanting (DAT) i.e., 20, 40, and 60 DAT, and the yield parameters were recorded at harvest. Significant differences were observed among various growth and yield parameters except for number of leaves, head polar and equatorial diameter. Maximum plant height i.e., 12.34 cm was observed in M0 at 20 DAT which was statistically similar with M3 (20.52 cm and 32.83 cm at 40 and 60 DAT, respectively). Number of leaves (3.91, 5.42, and 8.58), stem diameter (0.42 cm, 0.59 cm, and 1.08 cm), spread of plant (14.15 cm, 27.92 cm, and 40.96 cm), length of large leaf (10.58 cm, 16.9 cm, and 28.29 cm) and width of large leaf (5.7 cm, 9.76 cm, and 17.49 cm) were recorded higher in M3 for overall period of data collection (the data enclosed in parenthesis indicate maximum values at 20, 40, and 60 DAT, respectively). Similarly, yield parameters such as head equatorial diameter, head polar diameter, average head weight and yield were also recorded maximum in M3 as 12.46 cm, 11.53 cm, 205.5 gm and 13.69 MT/ha respectively. In overall, the control treatment performed the worst of all. The findings of this experiment suggest that the black plastic mulch gives best performance under field conditions at Gulmi district of Nepal followed by organic mulches.

Keywords: Mulching, black plastic mulch, organic mulches, broccoli, yield

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1 Introduction

Broccoli (*Brassica oleracea* var. *italica* L.) is an important cole crop that belongs to the family Cruciferae. It is a nutritionally valued crop grown worldwide, and is a floral vegetable enriched in vitamins, antioxidants, glucosinolates and anticarcinogenic compounds (Parente et al., 2013). Moreover, sprouting broccoli contains higher amount of minerals and vitamins as compared to other cole crops (Nonnecke, 1989). Due to this reason, broccoli can serve as an important nutritional source to solve the problem of malnutrition in Nepal. Broccoli can be grown on a wide range of soil types, ranging from light sand to heavy loam, or even clay that are well supplied with organic matter (Katyal, 1994). Fertilizer and moisture management are the important factors for assuring crop production. Broccoli is cultivated in Nepal during the winter season characterized by low rainfall. Crop cultivation during this dry period usually requires frequent and intense irrigation due to shallow root system of broccoli. Studies of various workers indicated that frequent irrigation gave the higher yields

of curd (Islam et al., 1996; Gomes et al., 2000). However, irrigation increases the cost of production resulting in unprofitable production of broccoli and make growers frustrated (Punetha, 2020). Mulching can minimize the water requirement of water and helps in retaining moisture (Amal et al., 1990).

Mulching is any kind of material that is applied on the top soil, it may be straw, compost, manure, chipped bark, plastic sheet etc (Prasad and Kumar, 1999). Mulch cover reduces the surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil (Khurshid et al., 2006). Mulching also helps to maintain desired soil temperature during winter and summer. Similarly, the use of organic mulches not only conserves the soil moisture, but also increases the soil nutrients through organic matter addition (Kumar and Kumar, 1990). Besides, organic mulches are produced as wastes in several forms, biodegradable in nature, economical to marginal farmers, and are available locally free of cost in every part of the nation. However, organic mulches can result in temporary reduction of soil mineral nitrogen and other nutrients too, and sometimes they can be even harmful for the major crop due to release of phytotoxins upon decomposition. On the other hand, plastic/polyethylene mulches have the properties of moderating the hydrothermal regimes of microclimate of crops, show positive effects on weed control, prevention of soil dryness and crusting, water saving by preventing evaporation from surface, prevention of soil erosion and reduction of nutrient loss by leaching (Singh et al., 2016). Therefore, in general, mulching can help to preserve soil moisture, maintain soil temperature and increase soil organic content which ultimately leads to better growth and yield of crops.

2 Materials and Methods

2.1 Experimental site

Geographically, the experimental area is located at 28°8′48″ N latitude and 83°4′31″ E longitude, Gulmi, Nepal. The region is characterized by subtropical highland climate or temperate oceanic climate with dry winters. Mean annual rainfall of this region is about 1377 mm with an average of 213 rainy days per year and an average humidity of 61%. Most of the rainfall is received during the month of July (about 22 rainy days) with precipitation of about 174 mm. May and June are the hottest months, and December and January are the coolest months of the year. Silt loam soil texture is predominant over this region which is generally rich in organic matter content.

2.2 Experimental layout and design

The experiment was laid out in randomized complete block design (RCBD) with four replications and five treatments of mulching viz. M0: Maize stalk, M1: Needlewood tree, Schima walllichii (Chopped stems and leaves), M2: Eupatory, Ageratina adenophora (Chopped stems and leaves) M3: Black plastic mulch, and M4: No mulch. The individual treatments were designed to a size of 1.8 m $\times$ 0.9 m. Each treatment consisted of four rows and three columns making the plant population of 12, and the total plant population of 240 in the field. The distance maintained between adjacent blocks and treatments were 0.5 m each. The sowing of seed was done at 19th of October, 2020, and the variety 'Centurion' was used. 38 days old healthy nursery seedlings of about 10-15 cm height were transplanted into the main field in a flat-bed system at 23rd November, 2020. The spacing of 45 cm $\times$ 30 cm was followed and the recommended dose of NPK was applied at the rate of 380 kg Urea: 180 kg DAP, and 80 kg MoP per hectare (MoAD, 2020). Well decomposed cow dung was applied at the rate of 10 MT/ha at the time of final land preparation, and the urea was applied in three split doses at 15, 30 and 45 days after transplanting (MoAD, 2020).

The experimental treatments were laid, cultivated and leveled thoroughly making a fine tilth of soil free from clods, stubbles and stones. Soil pH was measured initially before the start of research using kit-box, and recorded as 5.4 which were highly unsuitable for cultivation. Liming was done by mixing 1 kg agricultural lime and approximately equal quantity of wood ashes to correct the soil pH in a suitable range. The pH was again measured and found to be 6.1 which is good for cultivation. Before laying out the plastic mulches, slight irrigation was provided in the pre-determined treatments so as to make soil surface more uniform. All the mulches except the plastic mulch were finely chopped and laid after transplantation of nursery seedlings in a uniform manner. The fresh chopped green leaves and stems for mulching were sundried for 3 days, and then uniformly spread at the thickness of about 5 cm in the treatments. For plastic mulch, small openings were made before transplantation at a definite positions taking care of plant to plant and row to row spacing. Two edges of plastic sheet were incorporated in the furrows and covered slightly with soil. Hand hoeing operation was carried out in the control treatment. Irrigation was provided with the help of sprinkler at a regular interval of 2 days during vegetative stage, and on a daily basis during fruiting stage. Harvesting was done at the tight bud stage before flowering at different days for various treatments.

The data pertaining to vegetative attributes were recorded from three selected plants i.e., two from the middle of central rows and one randomly selected around the corner. However, the yield of curds was recorded treatment wise from individual plants. Plant height, number of leaves, spread of plant, stem diameter, length of large leaf and breadth of large leaf were recorded at 20 DAT and 40 DAT on 13th December, 2020 and 2nd January, 2021 respectively. Head polar diameter, head equatorial diameter, average head weight and yield were recorded at the different times of harvest in the month of March (March 1st, 7th and 15th). The mean values of all the treatments were calculated and analysis of variance through one-way ANOVA was carried out using Gen-stat analysis tool, Edition 15. The multiple comparisons were performed using Duncan's multiple range test (DMRT) at 5% level of probability.

3 Results and Discussion

3.1 Plant height

Mulching significantly influenced the height of broccoli plants at different growth stages *viz*; 20, 40 and 60 DAT. At 20 DAT, the greatest height (12.34 cm) was observed in M0 which was statistically similar with M1, M2 and M3, and the shortest height (9.25 cm) was observed in the control treatment i.e., M4 (Table 1). At 40 DAT, the tallest plant height (20.52 cm) was measured from M3 treatment which was statistically similar with M0, M1, and M2, and the smallest plant height (12.38 cm) was obtained from the control treatment (Table 1). Similarly, at 60 DAT, the highest plant height (32.83 cm) was recorded from black plastic mulch (M3) which was statistically similar with M2 and M0, and the lowest height (19.51 cm) was recorded from no mulch treatment (Table 1). It was revealed that the mulched treatments gave better plant height compared to non-mulched treatments. This might be due to the reason that the mulching increased crop growth rate (CGR), net assimilation rate (NAR), leaf area index (LAI) and relative growth rate (RGR). Similar finding was observed in the study of mulching effect in cabbage (Roy et al., 1990). Tallest plant height (34.91 cm) was obtained from T2 treatment (Black polythene) and the shortest plant (31.11 cm) from T1 treatment (control) in an experiment on broccoli conducted at horticulture farm of Bangladesh (Yasmin et al., 2021).

3.2 Stem diameter

Application of mulching significantly influenced the stem diameter of broccoli at 40 and 60 DAT. At 40 DAT, the maximum stem diameter (0.59 cm) was recorded in M3 which was statistically similar with that of M0, M1, and M2, while the minimum stem diameter (0.44 cm) was recorded in M4, the control treatment (Table 1). Maximum differences in statistical values for stem diameter were observed at 60 DAT where M3 exhibited the highest value (1.08 cm) while M4 exhibited the lowest value (0.39 cm) as shown in Table 1. This shows that the mulched treatments exhibited superiority in values of stem diameter over the control treatment at different times. This might be due to the reason that the mulching provides a favorable environment for the vigorous growth of root and shoot of the plant. Higher stem diameter of tomato was reported in straw and transparent polyethylene mulches in an experiment led by Arin and Ankara (2001).

3.3 Number of leaves

Mulching had no significant influence on the number of leaves at different days of data recording. Maximum values (3.91, 5.42 & 8.58) for the number of leaves were observed in M3 at 20, 40 and 60 DAT respectively, which were statistically similar with all the other treatments (Table 1). This result shows that the application of mulch materials does not have any significant influence on the number of leaves. In an experiment conducted by Adrian (2019) in Chinese cabbage, seedlings applied with peachpips and woodshavings treatments had the same average number of leaves at harvest, but they were not significantly different from control and newspaper treatment. However, the control had the smallest average number of leaves per plant.

3.4 Spread

Application of mulching significantly influenced the spread of broccoli plant at 40 and 60 DAT. the widest spread of plant (14.15 cm) was observed in M3 which was statistically similar with other treatments. At 40 DAT, the maximum spread (27.92 cm) was recorded in M3 while the minimum spread (17.23 cm) was recorded in M4 (Table 2). Similarly, the widest spread (40.96 cm) was observed in M3 at 60 DAT which was statistically similar with the values obtained in M0, M1, and M2, while the lowest value (22.91 cm) was observed in M4 (Table 2). This might be due to the reason that mulching increases the soil temperature and moisture content stimulating better root growth which could be differentiated more at the latter stages, and that in turns leads to greater plant growth. In an experiment conducted at Udaipur of India, it was found that the maximum plant height (70.91 cm), plant spread (53.05 cm) and highest number of branches (18.54) occurred with the application of black plastic mulch compared to other mulching treatment in marigold cv. Double mix (Chawla, 2006). Similarly, mulching gave comparable plant canopy diameter ranging from 20.31 cm to 21.66 cm and the nar-

Table 1. Effect of different mulches on plant height and stem diameter of broccoli

Treatments	Plant height (cm)			Stem diameter (cm)			Number of leaves		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
M0	12.34a	19.42a	29.21ab	0.37a	0.55a	0.98a	3.66a	4.91a	7.75a
M1	11.85a	17.63a	26.67b	0.36a	0.49ab	0.68b	3.5a	4.66a	7.33a
M2	11.71a	18.61a	30.43ab	0.36a	0.49ab	0.89ab	3.83a	4.66a	8.08a
M3	11.44a	20.52a	32.83a	0.42a	0.59a	1.08a	3.91a	5.42a	8.58a
M4	9.25b	12.38b	19.51c	0.32a	0.44b	0.39c	3.41a	4.25a	8.16a
CV (%)	10.9	10.7	8.8	20.6	12	22.8	3.66	4.78	7.98
LSD0.05	1.9	2.9	3.77	0.11	0.09	0.28	0.62	0.75	1.18
Sig. level	**	***	***	ns	**	***	ns	ns	ns

M0=Chopped and dried maize stalk, M1= Chopped and dried twigs and leaves of needlewood tree, M2= Chopped and dried twigs and leaves of eupatory, M3= Black plastic mulch, M4= No mulch; '*' represents significance at 5% level of probability (ns at $P > 0.05$, * at $P \leq 0.05$, ** at $P \leq 0.01$ and *** at $P \leq 0.001$, where P means F-probability value)

rowest canopy of 18.15 cm from non-mulched plants in lettuce in a research conducted by Castillo and Bacaya (2016).

3.5 Length and width of large leaf

Mulching also influenced significantly the length of large leaf at 40 and 60 DAT. At 20 DAT, the maximum value for length of large leaf (10.58 cm) was recorded in M3 while the minimum value (8.43 cm) was observed in M4, however no statistical differences were observed (Table 2). Likewise, at 40 DAT, the maximum length of large leaf (16.90 cm) was observed in M3 while the minimum length of large leaf (11.35 cm) was seen in the control treatment (Table 2). More significant differences in statistical values for the length of large leaf was recorded at 60 DAT where the maximum value (28.29 cm) was exhibited by M3 and the minimum value (15.46 cm) by the control treatment (Table 2). Apart these observations, application of mulching significantly influenced the width of large leaf at 20, 40 and 60 DAT. At 20 DAT, the maximum width of large leaf (5.70 cm) was recorded in M3 while the minimum width of large leaf (4.23 cm) was observed in M4 (Table 2). Similarly, at 40 DAT, the widest large leaf (9.76 cm) was observed in M3 while the narrowest large leaf (6.29 cm) was recorded in M4, the control treatment (Table 2). More significant differences were observed for the width of large leaf at 60 DAT where the maximum value (17.49 cm) was recorded in M3 and the minimum value (10.34 cm) in the control treatment (Table 2). The significant differences in length and breadth of large leaf might be due to the reason that mulching had profound influence on plant growth *viz.*, leaf area index (LAI), net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR), also influence on soil temperature and moisture (Islam et al., 2014). Similar finding was observed in an experiment conducted at Dhaka of Bangladesh in which mulching had a significant influence on leaf length and leaf breadth at 20, 40 and 60 DAT (Islam et al., 2014).

3.6 Head equatorial and polar diameter

Application of mulching had no significant influence on the head equatorial diameter and the head polar diameter of broccoli plant. Head polar diameter is the diameter of head across the vertical section of head, and head equatorial diameter is the diameter of head across the horizontal section of head of broccoli. The maximum head equatorial diameter (12.46 cm) was recorded in M3, while the minimum head equatorial diameter (10.02 cm) was observed in the control treatment (Table 3). Similarly, the greatest head polar diameter (11.53 cm) was recorded in M3, and the lowest head polar diameter (9.53 cm) was observed in the control treatment (Table 3). It might be due to the reason that mulched plants usually grow and mature more uniformly than non-mulched plants (Sarolia and Bhardwaj, 2012). Similar finding was observed in an experiment conducted at Uttarakhand of India in which highest equatorial (10.92 cm) and polar (11.64 cm) diameter was recorded with black plastic mulch whereas lowest in the control treatment (Punetha, 2020).

3.7 Average head weight and yield

Mulching significantly influenced the average head weight and the yield of broccoli. The maximum average head weight (205.5 gm) was recorded in M3 while the minimum average head weight (81.5 gm) was recorded from the control treatment (Table 3). Also, the highest yield (13.68 MT/ha) was recorded in M3 and the lowest yield (6.11 MT/ha) was recorded from the control treatment (Table 3). It might be due

Table 2. Effect of different mulches on spread of plant, length and width of large leaf of broccoli

Treatments	Spread of the plant (cm)			Length of large leaf (cm)			Width of large leaf (cm)		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
M0	12.73a	21.77b	32.42b	10.24ab	15.42a	24.57ab	4.83ab	8.15ab	13.55b
M1	11.95a	19.03bc	30.39b	9.93ab	14.72ab	21.34b	4.54b	7.16b	12.91bc
M2	11.65a	21.85b	38.43a	9.31ab	15.42a	25.24ab	4.54b	8.64ab	15.21ab
M3	14.15a	27.92a	40.96a	10.58a	16.9a	28.29a	5.70a	9.76a	17.49a
M4	11.07a	17.23c	22.91c	8.43b	11.35b	15.46c	4.23b	6.29b	10.34c
CV (%)	17.2	12.6	10.5	11.4	16.1	12.1	12.6	18	12.4
LSD0.05	3.26	4.18	5.36	1.69	3.65	4.26	0.92	2.22	2.66
Sig. level	ns	***	***	ns	ns	***	**	**	***

M0=Chopped and dried maize stalk, M1= Chopped and dried twigs and leaves of needlewood tree, M2= Chopped and dried twigs and leaves of eupatory, M3= Black plastic mulch, M4= No mulch; '*' represents significance at 5% level of probability (ns at $P > 0.05$, * at $P \leq 0.05$, ** at $P \leq 0.01$ and *** at $P \leq 0.001$, where P means F-probability value)

Table 3. Effect of different mulches on head equatorial and polar diameter, average head weight and yield of broccoli

Treatments	Head equatorial dia (cm)	Head polar dia (cm)	Average head wt. (g)	Yield (MT/ha)
M0	10.45ab	9.78b	110.7bc	7.89c
M1	10.10b	9.67ab	121.5b	8.50bc
M2	10.71ab	9.77ab	136.1b	10.66b
M3	12.46a	11.53a	205.5a	13.68a
M4	10.02b	9.53b	81.5c	6.11c
CV (%)	12.1	11.3	18.4	17.4
LSD0.05	2	1.74	37.1	2.51
Sig. level	ns	ns	***	***

M0=Chopped and dried maize stalk, M1= Chopped and dried twigs and leaves of needlewood tree, M2= Chopped and dried twigs and leaves of eupatory, M3= Black plastic mulch, M4= No mulch; '*' represents significance at 5% level of probability (ns at $P > 0.05$, * at $P \leq 0.05$, ** at $P \leq 0.01$ and *** at $P \leq 0.001$, where P means F-probability value)

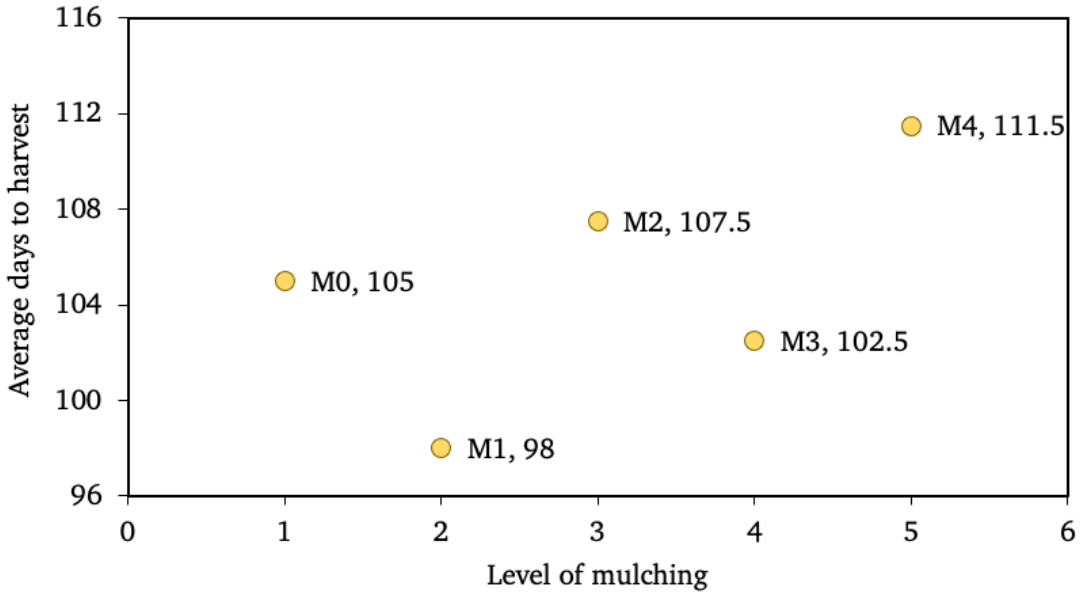

Figure 1. Average days to harvest of broccoli in the different treatments

to the reason that mulching leads to moisture conservation, higher soil temperature, weed control and increased mineral nutrient uptake through improved root temperature which ultimately results in better quality fruits and higher yield (Mario et al., 1994). Similar results were observed in the other experiment in which the maximum head weight (496.19 g) and yield (16.65 Mt/ha) was recorded with black plastic mulch and minimum head weight (272.43 g) and yield (10.18 Mt/ha) was recorded with control treatment (Punetha, 2020).

3.8 Average days to harvest

Harvest was done at various dates on March 1st, 7th and 15th for various treatments. Average days to harvest was recorded minimum in M2 (98 DAT) followed by M3 (102.5 DAT) and maximum in the control treatment (111.5 days) as shown in Fig. 1. It might be due to the favorable temperature during growing season in the mulched treatments. Applications of polyethylene films as mulch have shortened growing season and enhanced earliness and yield in different vegetable crops like sweet corn, eggplant, tomatoes, muskmelons, peppers, cucumbers, summer squash, okra and watermelons (Goreta et al., 2005).

4 Conclusion

The beneficial influence of organic and synthetic mulches is well discussed among the researchers and the farmers. Several researches have shown that the mulch provides congenial environment to the plant thereby, enhancing its growth and productivity. Similar to those findings, in this experiment too, application of mulch materials enhanced the growth and yield of broccoli compared to no-mulch-control-treatments. Among different mulches, black plastic mulch can be considered as best treatment in terms of growth and yield in broccoli at gulmi district of Nepal. Nevertheless, organic mulches can be utilized as eco-friendly mulching materials since they are easily biodegradable and they act better compared to no mulching whatsoever. The experiment needs to be further elaborated in a temporal and spatial basis for accurate and precised results.

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Conflict of Interest

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

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