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Effects of Different Mulching Practices on Garlic (*Allium sativum* L.) Growth and Production

Amrit Kumar Bohara[1,a,*], Subash Saud[2,b], Abhishek Pokhrel[1,c], Susmita Subedi[1,d]

[1]*Institute of Agriculture and Animal Science (IAAS), Tribhuvan University (TU), Prithu Technical College, 22414, Lamahi, Dang, Nepal*
[2]*Faculty of Agriculture, Agriculture and Forestry University, 44209, Rampur, Chitwan, Nepal*
[*]*Corresponding author*

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A B S T R A C T

Garlic (*Allium sativum* L.) is a shallow-rooted crop mostly grown for cloves, which are used as a food flavoring condiment. Mulching helps to keep soil moisture by lowering energy loss through evaporation and preventing vapor transfer. A field study investigated how different mulches affect the garlic growth metrics. The experiment was conducted in the Chitwan District of Nepal from December to April 2022 under a randomized complete block design with three replications and five treatments (control, polythene mulch, straw mulch, banana leaf mulch, and sawdust mulch). The results reveal that the type of mulching materials employed substantially impacts on garlic growth and clove yield. Rice straw mulch exhibited the highest plant height (70.69cm) at 120 DAP followed by sawdust (64.44cm) and banana leaves (62.34cm). At 120 days after planting, leaf length was found to be statistically similar under rice straw (43.36) and plastic mulch (41.56 cm). Plastic mulch showed the highest results in number of leaves per plant (7.6), Stem diameter (1.58cm), Bulb weight (44.61gm),Bulb diameter(5.11cm), Root length(8.48cm) and Total yield (15.99t/ha). On the other hand, saw dust had a greater impact on bulb length (6.05cm). Notably, plastic mulch regularly outperformed other treatments in most criteria, with rice straw following closely. Based on these findings, plastic mulch appears to be the best option for garlic production.

[a] *boharaamrit2037@gmail.com* *https://orcid.org/0009-0008-5961-1494*
[b] *subashsaud1111@gmail.com* *https://orcid.org/0009-0008-1469-1750*
[c] *abhipokhrel777@gmail.com* *https://orcid.org/0009-0001-1544-4312*
[d] *susmitasubedi58@gmail.com* *https://orcid.org/0009-0004-2326-5471*

Introduction

Garlic (*Allium sativum* L.) belongs to the family Alliaceae and genus Allium and is a shallow-rooted crop (Karaye& Yakubu, 2006). It ranks as the second most widely used Allium after onion with a characteristic pungent smell(Kabir et al., 2013). Garlic is mainly cultivated for its cloves; however, its leaves and flower stalks are also consumable. Garlic was produced 74,763 Metric tons in 9943-hectare area in Nepal in 2021/22 (MoALD, 2023).

The probable reason for the decrease in yield is due to the reduction of soil moisture during the early growth phase of garlic. During this period, garlic requires supplemental irrigation, but irrigation facilities are often unavailable in almost all parts of Nepal. Mulching helps to retain soil moisture by reducing the energy lost through evaporation and preventing vapor transport. Garlic, being a thermo-photo-sensitive crop, has its vegetative growth and bulb development significantly influenced by the growing environment. Manipulating growing conditions through cultural practices like mulching has the potential to improve yield (El-Beltagi et al., 2022).

Mulches reduce the quantity of energy consumed in evaporation by blocking the transport of vapor (Farzi et al., 2017). Mulches made from paper, straw, weed or trash form an insulating layer on the soil surface, helping to conserve moisture and lower soil temperature. Using plant residues and synthetic materials as mulch is a well-proven technique for increasing the profitability of various horticultural crops (Gimenez et al., 2002). The primary aim is to enhance crop growth by regulating soil temperatures and maintaining soil moisture (Mutetwa &Mtaita, 2014). Mulches can also control weeds and protect crops from insect pests or diseases (Ngouajio et al., 2008). Mulching helps in a significant increase in N, P and K uptake compare to un-mulched condition The result obtained from the use of mulching led to the increase in plant growth, yields and bulb size in the garlic (Seifu et al., 2017). Mulch may be permanent (e.g. plastic sheeting) or temporary (e.g. bark chips) which can be applied to bare soil, or around existing plants.

Organic mulches will gradually break down and become part of the soil over time (Yimer, 2020). This is a great advantage, because this decomposition adds organic matter to soil, helping the soil to better retain water and nutrients and produce healthier plants. Inorganic mulch such as plastic mulch constitutes the largest volume of mulch used in commercial garlic production. Plastic mulches typically consist of polyvinyl chloride or polyethylene films. Due to their higher permeability to long-wave radiation, they can increase the temperature around plants during the night in winter. Hence, polyethylene film mulch is preferred as a mulching material to produce horticultural crops (Bhardwaj, 2013).Additional factors to consider when selecting mulch include cost and availability.

Each mulching technique has its benefits and effects on garlic growth parameters. Straw mulch can provide a more favorable microclimate for plants than plastic mulch (Atif et al., 2019). Rice straw provides long-term benefits in obtaining better plant height through the addition of organic matter and recycling of nutrients. Organic mulches reduce nitrate leaching, improve soil physical properties, prevent erosion, provide organic matter, regulate temperature and water retention, improve nitrogen balance, participate in nutrient cycling and increase biological activity (Yimer, 2020).The exceptional effectiveness of straw mulch in increasing plant height demonstrates its usefulness as a sustainable solution for improving garlic production (Seifu et al., 2017)

Therefore, a deeper knowledge of mulching in garlic cultivation is crucial for creating management strategies that maximize moisture retention and improve garlic yield. Thus, the study was conducted to assess how different mulches affect garlic growth parameters.

Materials and Methods

This research was carried out in the Chitwan district of Nepal during the growing season from December to April 2022. The experiment field was at the geographical location of 27° 39' N latitude and 84° 20' E longitude at an altitude of 182 masl and has a subtropical climate. Garlic grows best in a cool climate, with temperatures between 10–20°C during its early growth stage and around 20–25°C for proper bulb formation. It thrives in well-drained soil and does not tolerate excessive moisture. The majority of soils found in this region are in pH range of 6.2 (slightly acidic) to 7.8 (alkaline). The experiment was conducted using a randomized complete block design which consists of 5 treatments (control, polythene mulch, straw mulch, banana leaves mulch and saw dust mulch) with three replications. Mulch materials were obtained from the local market. Polythene mulch was 25 microns and other mulches were chopped in small pieces so that they breakdown easily. The plot covered an area of 4.2 square meters with clove planted 15 cm apart between rows and 10cm apart within rows. The spacing between plots was 0.5m, while the distance between blocks was 1m.

The field was prepared on December 15th, 2022, by 2-3 deep plowing followed by leveling, one week before plantation. Weed debris was cleared and soil was finely tilled to ensure uniform moisture distribution, optimal temperature, and proper root penetration as well as consistent leveling was done to prevent waterlogging and promote effective seed germination, emergence, and establishment. The plot was carefully marked out with sufficient spacing between and within rows using common farm tools, tape, hoe, rope and rake. The detailed layout was arranged before sowing. Cloves of local cultivars of the same size obtained from research center were used for planting. Mulching was done immediately after planting the cloves. Chemical fertilizer was delivered via urea, DAP, and MOP at a rate of 60:40:50 kg NPK/ha-1. Complete doses of potassium and phosphorus, together with half dose of nitrogen were applied as a basal dose. The half left over nitrogen was side dressed in two applications, half at three weeks after plant emergence and remaining half was applied at five weeks later.

Observation

Data collection

The growth parameters data were gathered during the field experiment by randomly sampling plants from the two central rows in each plot. The following parameter was recorded on five randomly taken plants from each plot.

Growth parameters

Plant height (cm)

Height of the plants was measured from selected plants from each plot. It was measured from the soil surface to the tip of mature leaf at 30, 60, 90. 120 days after planting.

Leaf Length (cm)

It was measured using the ruler from the base of the leaf to the tip of the leaf at 30, 60, 90 and 120 days after planting.

No. of leaves per plant

It was the mean number of leaves excluding senescent and newly developing leaves produced by sampled plants at 30, 60, 90 and 120 days after planting.

Yield parameters

Stem diameter

Stem diameter of plants was measured at the time of harvest using a vernier caliper. It is expressed in centimeters (cm).

Bulb weight

The fresh weight of garlic bulbs was measured using a digital balance for higher accuracy.

Bulb length

Bulb length was measured using a Vernier caliper after harvesting the garlic bulbs to show greater accuracy. Bulb length was measured from the tagged plants.

Bulb diameter

The bulb diameter was measured using a Vernier caliper after harvesting the garlic bulbs.

Root length

Root length was measured by using measuring scale from the base of the bulb (root plate) to the tip of the longest root.

Total yield

The total weight of the entire garlic population for each treatment in each plot was measured using a digital weighing balance and expressed in kilograms (kg).

Statistical analysis

Data entry and processing were performed using Microsoft Office Excel and R-studio 4.2.2 was used for statistical analysis of the traits in a Randomized Complete Block Design (RCBD) design. Ducan's multiple range test (DMRT) was employed to detect variations in treatment means at the 5% level of significance.

Results and Discussion

Plant Height

A significant effect was observed on plant height under different mulching except at 30 days after planting (DAP) (Table 1). After 30 DAP, the maximum height of garlic was observed in the plastic mulch (24.58 cm) and the minimum in plants treated with banana leaves mulch (20.47 cm). After 60 DAP, the maximum height was observed in plants treated with rice straw mulch (49.83 cm) and the minimum in plants treated with control (42.61 cm). The plant heights of plants in plastic mulch treatment (48.47 cm) were found to be statistically similar to plant heights of plants treated with rice straw mulch, whereas the plant heights of plants treated with sawdust (44.64 cm) were statistically similar to plants under control after 60 days. The maximum height in garlic after 90 DAP was observed in plants at plastic mulch treatment (73.58 cm) and the minimum in plants treated with control (62.19 cm). After 120 DAP, the plant heights of garlic in every treatment showed decreasing trends with the maximum in the rice straw treatment (70.69 cm) and a minimum in the control treatment (58.56 cm).

The drop in plant height at 120 DAP is caused by senescence, which occurs when older leaves yellow, dry, and die. This natural aging process can cause a decline in plant height when the leaves wilt and lose turgidity(Bresson et al., 2018). Furthermore, minerals and carbohydrates begin to translocate from the leaves to the developing bulbs as the plant becomes older; this reallocation of resources reduces leaf growth and may result in a drop in plant height(Schippers et al., 2015).

Number of Leaves

At 30 DAP, the highest and lowest numbers of leaves were found in plants with plastic mulch (3.83) and sawdust mulch (3.27) (Table 2). The leaves number in plants in control (3.40) and banana leaves mulch (3.40) and rice straw mulch (3.77) was statistically similar. After 60 DAP, the same trend was seen with the highest number of leaves on plants treated with plastic mulch (5.10) and the lowest in plants treated with sawdust mulch (4.40). Similarly, the highest numbers of leaves were observed in plastic mulch after 90 DAP (7.93) and 120 DAP (7.6). After 90 DAP, the lowest number of leaves was found in plants of the control treatment (6.83) and plants with banana leaves mulch (6.83), whereas after 120 DAP, the lowest number of leaves were found in plants treated with sawdust mulch (6.13).

Table 1. Effect of different mulching on Plant height

Treatments	Plant height			
	30 DAP	60 DAP	90 DAP	120 DAP
Control	23.68ab	42.61b	62.19d	58.56c
Banana leaves	20.47b	43.87b	66.89c	62.34bc
Saw dust	20.84b	44.64b	68.59bc	64.44b
Rice straw	23.83ab	49.83a	73.58a	70.69a
Plastic	24.58a	48.47a	71.24ab	61.39bc
LSD (p<0.05)	3.24	3.24**	4.23**	4.06**
CV%	7.57	3.75	3.28	3.39
Grand mean	22.68	45.88	68.51	63.48

DAP: Days after planting, LSD: Least significant difference, CV: Coefficient of Variation.

Table 2. Effect of different mulching on the number of leaves per plant

Treatments	No. of leaves/plant			
	30 DAP	60 DAP	90 DAP	120 DAP
Control	3.4ab	4.83 ab	6.83 b	5.37c
Banana leaves	3.4ab	4.63bc	6.83b	5.47 bc
Saw dust	3.27b	4.4c	6.57c	6.13b
Rice straw	3.77ab	4.9ab	7.2ab	6.2b
Plastic	3.83a	5.1a	7.93a	7.6a
LSD (p<0.05)	0.51	0.26**	0.81**	0.75***
CV%	7.76	2.92	6.18	6.83
Grand mean	3.53	4.77	6.9	6.15

DAP: Days after planting, LSD: Least significant difference, CV: Coefficient of Variation.

Table 3: Effect of different mulching on Length of leaves.

Treatments	Length of leaves (cm)			
	30 DAP	60 DAP	90 DAP	120 DAP
Control	14.67ab	32.76b	40.99c	29.24c
Banana leaves	12.83b	31.84b	43.02bc	35.47b
Saw dust	12.53b	34.03ab	45.32b	33.89b
Rice straw	16.37a	37.12a	49.73a	43.36a
Plastic	15.47a	36.29a	48.73a	41.56a
LSD (p<0.05)	2.28*	3.19*	2.48***	4.05***
CV%	8.45	4.94	2.89	5.86
Grand mean	14.37	34.41	45.56	36.71

DAP: Days after planting, LSD: Least significant difference, CV: Coefficient of Variation.

The ability of plastic mulch to retain a larger number of leaves throughout the growing period demonstrates its usefulness in maintaining favorable growing conditions. According to Kumar Rai & Negi, (2021)maximum number of leaves is found in the treatment that could provide favorable moisture conditions and temperature. Applying organic mulches like rice straw, and banana leaves also contributes positively to the number of leaves, but their benefits may be less noticeable than those of plastic mulches. Organic mulches show positive results at later growth stages when the nutrient needs of plants increase. Leaves number rises to a certain point in plant development and then decreases. This finding aligns with results obtained by (El-Magd et al., 2013)

Leaf Length

At 30 DAP, the maximum leaf length of garlic was found in plants treated with rice straw mulch (16.37 cm) and the minimum leaf length was found in plants treated with sawdust mulch (12.53) (Table 3). The leaf length for garlic plants treated with banana leaves mulch (12.83 cm) was statistically par with plants grown with sawdust mulch. After 60 DAP, the maximum length of garlic leaves was observed in rice straw mulch (37.12 cm) and the minimum length was observed in banana leaf mulch (31.84 cm). Similarly, the longest leaf length was observed in plants treated with rice straw mulch at 90 DAP (49.73 cm) and 120 DAP (43.36 cm) respectively. The leaf lengths of garlic plants treated with plastic mulch were statistically similar to rice straw mulch in all the observations.

The number of leaves at 30, 60, 90, and 120 DAP were positively influenced by the effect of mulching. Similar findings for plastic mulch were also reported by (Jamil et al., 2005). Mulch retains moisture and improves nutrient availability to plants, resulting in overall plant growth and development, including number of leaves (Awasthi et al., 2022).Mulch produced higher leaf pigments than control plants. Mulched plants produced higher levels of chlorophyll-a, chlorophyll-b, and total chlorophyll, as well as longer leaves (Baten et al., 1995).

Stem Diameter

The wider stem diameter was recorded in plastic mulch (1.58 cm) and the narrow in sawdust mulch (1.18 cm). The stem diameter of the control treatment (1.15 cm) was statistically similar to sawdust mulch and the stem diameter of banana leaves mulch (1.36 cm) was found statistically at par with rice straw mulch (1.45 cm) (Table 4).

These results were consistent with the conclusions of Jamil et al., (2005). A study by Chen et al., (2024)also highlighted the effectiveness of plastic mulch on stem diameter, due to improved soil conditions and reduced weed competition. Mulch helps conserve soil moisture by reducing evaporation and maintaining more stable soil temperatures. Plastic mulch, in particular, is very effective in this regard and can help plants grow better and have larger stem diameter (Ahmad et al., 2022).

Bulb Weight

The highest bulb weight was found in plants treated with plastic mulch (44.61 gm) followed by rice straw (39.56 gm) and lowest in plants treated with control (28.41gm).

Jamil et al., (2005) documented similar results for the bulb weight where they observed higher bulb weight in plastic mulch followed by rice straw. Seifu et al., (2017) studied only polyethylene mulch and therefore reported that this type of mulch significantly enhanced bulb weight of garlic. The fate of stem expansion and bulb formation is regulated by competition for resources between developing bulb and inflorescences (Atif et al., 2019).

Bulb Length

The maximum bulb length was observed in sawdust mulch (6.05 cm) and the minimum in the control treatment (5.16 cm). The bulb length of garlic grown with rice straw mulch (5.51 cm) was statistically at par with plants treated with banana leaves mulch (5.41 cm) and plastic mulch (5.73 cm).

The slow decomposition of sawdust mulch adds organic matter to the soil, improving soil structure and enhancing the availability of important nutrients like carbon and nitrogen (Haque et al., 2003). Because of their slower breakdown, garlic bulbs keep moisture for extended periods, maintain warmth, and grow longer (Iqbal et al., 2020).

Bulb Diameter

The longest bulb diameter was observed in plastic mulch (5.11 cm), whereas the shortest bulb diameter was observed in the control treatment (4.38 cm). The bulb diameter of garlic in rice straw mulch (4.99 cm) was statistically equivalent to that observed in the plastic mulch. In contrast, the bulb diameter of plants treated with banana leaves mulch (4.82 cm) was statistically at par with sawdust mulch (4.73 cm).

Plastic and rice straw mulches tend to give the best circumstances for bulb development, whereas banana leaves and sawdust offer minor advantages. Islamet al., (2007)recorded the highest bulb diameter for plastic mulch. As reported by Yimer, (2020) garlic grown on black plastic produced larger bulb diameters and marketable weights than garlic grown in bare soil.

Root Length

Similar figures for root length were observed in all mulch treatment, with the longest in plants grown with plastic mulch (5.11 cm) followed by rice straw (8.36). Root lengths were statistically similar in all treatments observed.

Garlic being a cold-season crop requires low temperatures for proper growth. High temperatures throughout the growing period can limit root elongation and density, and reduce water and nutrient intake (Larkin, 2020). Rice straw boosted soil water content and lowered soil penetration resistance, which enhanced root growth (Paul et al., 2021).

Total Yield

A statistically significant effect of mulches was observed on the yield of garlic (Table 4). The highest yield was observed in plastic-treated mulch (15.99 t/ha) followed by rice straw (13.1 t/ha) and the lowest in the control treatment (9.49 t/ha). The performance of garlic yields under different treatments is shown in Figure 1.

Jamil et al., (2005) reported plants grown for the whole season under any mulch produced the highest yield than those grown without mulch.

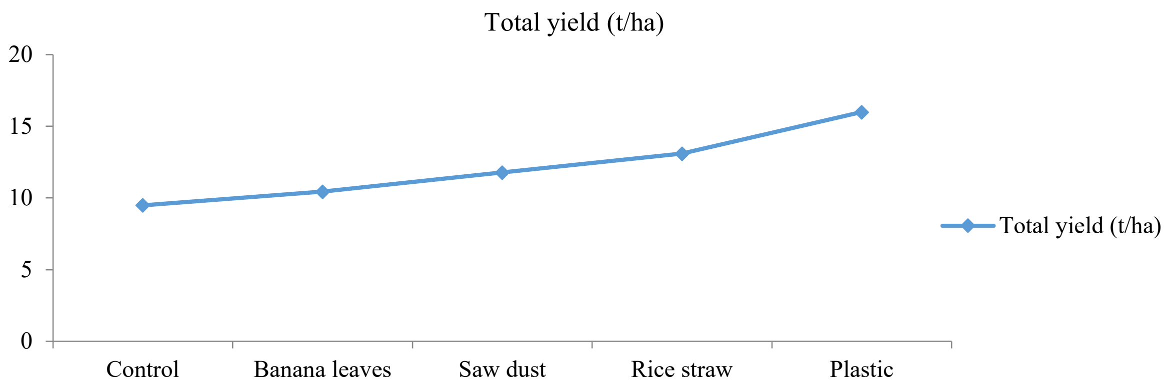

Figure 1. Performance of garlic yield under different treatments

Table 4. Effect of different mulching on stem diameter, bulb weight, bulb length, bulb diameter, root length, and total yield.

Treatments	Stem diameter (cm)	Bulb weight (gm)	Bulb length	Bulb diameter	Root length	Total yield (t/ha)
Control	1.15c	28.41d	5.16d	4.38b	8.14a	9.49d
Banana leaves	1.36b	37.46bc	5.41c	4.82ab	7.43a	10.44cd
Saw dust	1.18c	34.58c	6.05a	4.73ab	7.94a	11.78bc
Rice straw	1.45b	39.56b	5.51bc	4.99a	8.36a	13.1b
Plastic	1.58a	44.61a	5.73b	5.11a	8.48a	15.99a
LSD (p<0.05)	0.13***	3.9***	0.24***	0.46*	1.67	1.6***
CV%	4.95	5.74	2.33	5.07	11.68	7.01
Grand mean	1.34	36.93	5.57	4.81	8.07	12.16

LSD: Least significant difference, CV: Coefficient of Variation.

Each mulch maintained ideal soil moisture, regulated temperatures for plant growth, suppressed weed growth, and increased garlic yields compared to normal control conditions (Baten et al., 1995). According to Najafabadi et al., (2012), mulching increases bulb yield and improves quality indices such as ash percent, TSS, and vitamin C in garlic.Islam et al., (2007) conclude garlic produced in black polyethylene mulch was suitable for increasing garlic production.

Conclusion

The findings show that the growth and yield of garlic are significantly impacted by the types of mulching materials used. Notably, plastic mulch consistently outperformed other treatments on most parameters; followed closely by rice straw. Plastic mulch offered better circumstances for overall garlic development, but rice straw showed improved plant height because it could produce a better growing environment. Additionally, bulb length was found to be promoted by sawdust mulch.

However, the long-term effects of using plastic mulch must be taken into consideration. Studies have shown that long-term use of plastic mulch can lead to a decline in soil quality, putting risk to sustainable agricultural practices. In contrast, rice straw emerges as a better option for the farmer as it is cost-effective, organic and easily available, making it an ideal choice for garlic production. Considering these results, straw mulch is recommended for garlic cultivation in different agro-climatic conditions, especially for farmers looking for a long-term solution to improve soil health and productivity. Otherwise, plastic mulch is the most effective for garlic production.

Declarations

Ethical Approval Certificate

Not Applicable

Author Contribution Statement

A.K.B. and S.S.: Conceptualization, methodology, project administration, supervision, data collection, investigation, formal analysis, writing the original draft.

A.P. and S.S.: Methodology, investigation, data collection, formal analysis, review and editing

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Conflict of Interest

The authors declare no conflict of interest.

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