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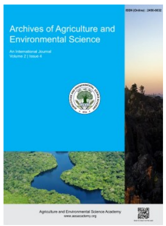

ORIGINAL RESEARCH ARTICLE

CrossMark

Effect of different mulching materials on growth and yield of garlic (*Allium sativum* L.) in Khajura, Banke, Nepal

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ABSTRACT

A field experiment was conducted in Khajura, Banke, Nepal, to evaluate the effect of different mulching materials on the growth, and yield of garlic (*Allium sativum* L.). The study was based on a Randomized Complete Block Design (RCBD) consisting of four replications and five treatments, i.e. control (no mulch), black plastic, rice straw, wheat straw and lentil straw. Data were recorded on germination, growth parameters, yield attributes and soil moisture status. Statistical analysis revealed significant effects of mulching materials on most growth, yield, and soil moisture parameters. Plastic mulch outperformed all other treatments with tallest plants (68.13 cm), maximum number of leaves (5.83) along with maximum bulb diameter (4.30 cm), cloves per bulb (18.35), bulb weight (27.06 g), total biomass yield (19.96 t/ha), economic yield (15.08 t/ha), and soil moisture content (21.43%). Lentil Straw followed it with plant height of 67.05 cm, 5.56 leaves, bulb diameter of 4.30 cm, 15.85 cloves per bulb, bulb weight of 24.72 g, total biomass yield of 17.47 t/ha, economic yield of 13.77 t/ha, and soil moisture content of 19.51%. Rice straw and wheat straw showed considerable performance over control plots with economic yields of 11.57 t/ha and 11.68 t/ha, respectively, compared to only 7.67 t/ha in bare soil. Based on this study, plastic mulch is the most effective practice for maximizing garlic productivity in Khajura, Banke and Lentil straw mulch is suggested as an environmentally sustainable alternative.

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INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important spice crops belonging to the genus Allium and family Alliaceae. It is one of the oldest known horticultural crops, with its center of origin in central Asia and its closest wild relative, *Allium longicuspis* (Kamenetsky *et al.*, 2004). The allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine are key bioactive compounds found in garlic (Shang *et al.*, 2019). These elements are found to have been anti-inflammatory, antithrombotic, hepatoprotective, antimicrobial, antihyperglycemic, antidiabetic, and antitumor functioning (Tudu *et al.*, 2022; Lidiková *et al.*, 2022). Due to this, it was used for traditional medication, apart from culinary purpose over centuries. Despite almost all parts of garlic, except roots, being useful, cultivation is primarily done for its bulb, which consists of multiple cloves. Garlic is globally grown over 14.22 lakh hectares and had a total production of 237.70 lakh tons and an average productivity of 16.71 t/ha (Prahlad *et al.*, 2021). However, the national average productivity of garlic in Nepal is just 6.28 t/ha (Giri *et al.*, 2018), which is significantly lower than that of most garlic-producing countries. This indicates that there is still a large potential for enhancing garlic production by adopting better agronomic methods.
Inadequate moisture availability, especially during the critical

growth stage of garlic, is a major reason for the decreasing trend of garlic production in Nepal. Garlic is highly sensitive to moisture stress, which can lead to up to 60% reduction in yield (Islam *et al.*, 2015). In the subtropical plains of western Nepal, including Khajura Banke, biophysical and socioeconomic constraints often challenge garlic production. While sufficient moisture availability is significant for garlic bulb initiation and development (Khokhar, 2022), farmers face issues like irregular winter rainfall and limited access to reliable irrigation facilities. This leads to a serious moisture deficit, resulting in poor germination, weak stand establishment, and reduced bulb development. Garlic, being a thermo-photosensitive crop, growing environment has a significant impact on both its vegetative growth and bulb development (Atif *et al.*, 2019). Therefore, the adoption of suitable agronomic practices such as mulching can be critical in improving soil microclimate, conserving moisture, and enhancing overall garlic productivity.

Mulching is the practice of covering the surface of soil with these materials to reduce moisture loss and to balance wide variations in diurnal soil temperatures in the root area of the cultivated crop (Ghouse, 2020). Studies have found that the use of plant residues and synthetic materials in the form of mulch is a well-adapted and proven technique for increasing the profitability of various horticultural crops (Mutetwa & Mtaita, 2014). Mulching practice has been found to reduce the soil moisture evaporation by 50% and enhance the water use efficiency in the field (Hatfield *et al.*, 2001). It also minimizes the nutrient losses by reducing the leaching of nitrogen immobilizing post-harvest residual nitrate in the soil (El-Beltagi *et al.*, 2022; Doring *et al.*, 2005). Conservation of irrigation water, reducing soil erosion and leaching of fertilizer, controlling weeds, enhancing early growth and increasing overall yield are key benefits of mulching in garlic production. The mulching practice further enhances the retention, availability and uptake of nutrients in soil through better nutrient redistribution, reducing gaseous nutrient losses through soil coverage, and contributing additional nutrients through the decomposition of mulch (El-Beltagi *et al.*, 2022; Iqbal *et al.*, 2020). Therefore, mulching is an effective agronomic practice that contributes to soil moisture conservation, nutrient availability, and stable soil microclimate in garlic production.

Mulching materials may be either organic (e.g. rice husk, straw, dried leaves) or inorganic (e.g. plastic sheets). Each mulching has its unique advantage and influence on the crop growth and yield performance (Bohara *et al.*, 2025). Organic mulches gradually decompose and become part of the soil over time (Choudhary *et al.*, 2025). This contributes to better soil health by improving the water and nutrient retention capacity through the addition of organic matter. The increase in organic matter also promotes microbial activity in soil, leading to improved soil structure and increased fertility (Liang *et al.*, 2025). They reduce the soil temperature fluctuations and provides more stable edaphic environment for the garlic roots. Additionally, some organic mulches have the ability to repel pests through physical barriers or their aromatic qualities (Malik *et al.*, 2025). Inorganic mulches, however, do not decompose over time. They, hence, enhance soil microclimate and promote immediate yields without contributing to long-term soil fertility. They contribute to a significant increment in soil temperature, allowing for earlier planting and faster crop growth (Choudhary *et al.*, 2021). Due to high permeability to radiation, inorganic mulches like polyethene films increase the temperature around plants during the night in winter (Demo & Bogale, 2024). Zhang *et al.* (2021) have reported that an increase in average soil temperature in garlic by plastic mulch contributes to improved bulb size and higher yield in garlic. These opaque mulches block sunlight and prevent it from reaching the soil, inhibiting germination and growth of weeds by ceasing photosynthesis (Demo & Bogale, 2024). The non-degradable nature of inorganic mulches also reduces the frequent replacement need and allows reuse over multiple cropping seasons. The choice between these organic and inorganic mulching materials is shaped by local availability, economic considerations, and management goals.

Despite well-documented benefits of mulching on several horticultural crops, there is very limited evidence for its relevance in the subtropical conditions of western Nepal, particularly for garlic production in Khajura, Banke. Existing studies are more focused on a single mulch type, and do not explore the systematic comparison between locally available organic mulches and globally effective plastic mulch. Besides, farmers in Khajura still lack location-specific, experimentally validated recommendations on which mulching material offers the best balance between yield gain, input cost, and long-term soil health. The novelty of this study lies in its comparative evaluation of both organic and inorganic mulching materials under the specific environmental conditions of Khajura, Banke. Hence, this study aims to evaluate the effect of different mulching practices (organic and inorganic) on germination, growth parameters (plant height and leaf number), yield attributes (bulb diameter, bulb weight, number of cloves per bulb, total biomass yield and economic yield) and soil moisture status of garlic under Khajura conditions. This study, therefore, provides a practical and locally relevant guidance on mulching options that can enhance garlic productivity and resource‐use efficiency for smallholder farmers in western Nepal.

MATERIALS AND METHODS

Site selection and research design

The field experiment was conducted from November 16, 2024, to March 25, 2025, in Khajura Rural Municipality of Banke District of Nepal. The experimental area is situated in the subtropical region at an altitude of 130 to 164 meters above sea level, with coordinates 28.1204° N, 81.5857° E. The area of this rural municipality is 101.59 sq.km. The local garlic variety used by farmers from the region was chosen for the study. The research experiment was conducted in a Randomized Complete Block Design (RCBD) with four replications and five treatments. There were 20 experimental plots in total, with dimensions of 1.025 m × 0.7 m, with an area of each plot being 0.7175 sq m. The plots were separated by 0.5 m within a block, and each block was 1 m apart from the others. There were 49 plants in each plot with a row-to-row distance of 15 cm and plant-to-plant distance of 10 cm following the methodological approach of Giri *et al.* (2023).

Field preparation

The field was prepared on November 9, 2024, i.e. one week before sowing of cloves. A power tiller was employed with two ploughings followed by levelling. Weeds from the field were removed after first ploughing, and fine tillage was conducted to allow for proper root penetration. Manual levelling after final tillage was carried out to prevent waterlogging in the field.

Fertilizer application

The recommended dose by Agriculture and Livestock Diary (2025), i.e. 12:12:4 kg per ropani, i.e. 235.8: 235.8: 47.2 kg NPK per ha, along with 20 tons/ha of farmyard manure (FYM) per hectare, was applied in the field. Fertilizer doses were calculated for each area of the plots. Full dose DAP was applied as a basal dose to supply both P and part of N. MOP was also applied as a complete basal to supply K. Half of urea was applied as a basal dose, and the remaining half in two split doses at 30 DAP and 60 DAP, respectively.

Seed rate and sowing

The recommended seed rate as per Agriculture and Livestock Diary (2025), 2500g per ropani (49.13 kg/ha), was followed in the experiment. Uniform cloves of the local garlic variety were sown at a depth of 5-6 cm below the soil. There were 20 plants in each plot with a row-to-row distance of 15 cm and plant to plant distance of 10 cm.

Mulching materials

Mulching was done immediately after planting cloves. Black plastic, rice straw, wheat straw and lentil straw were used as mulching material. No mulching materials were used in the control plots. The 30 microns' black plastic sheet was the only inorganic mulch. All other organic mulches were chopped into small pieces to allow their easy breakdown over time in the field.

Intercultural operations

Uniform irrigation was applied throughout the field to ensure adequate moisture supply to the field. Immediately after the sowing of cloves, light irrigation with a rose can was performed from above the mulch to allow proper germination of the cloves. Irrigation was applied daily during the early growth stages to keep the soil sufficiently moist for sprouting. Irrigation at 2-3-day intervals was carried out in vegetative stages, depending upon soil conditions. As the bulb initiation and development phase is more sensitive to moisture stress, daily irrigation with a rose can was carried out. The frequency of irrigation was gradually reduced as the crop approached its maturity and was completely stopped a week before harvesting, to facilitate bulb curing and ease of harvesting. No significant weeding was carried out in the plots to allow the mulching materials to play their role in weed suppression, which could influence the growth and yield of the crop.

Sampling and data collection

From each unit plot, five plants were selected using simple random sampling and were marked using colored threads for identification. As individuals in the border row usually enjoy better conditions to obtain a higher yield (Sun *et al.*, 2023), border plants were not sampled to eradicate this border effect in the research. From the selected samples, data were collected on growth and yield parameters, including plant height, number of leaves per plant, bulb diameter, bulb weight, and number of cloves per bulb. The mean of the five sampled plants per plot was used for statistical analysis. For the yield of bulbs, the weight was taken from the whole plot and converted to tons per ha.

Harvesting: The garlic crop was harvested on March 25, 2025. At the time of harvesting, the selected sample plants (marked earlier with colored threads) were carefully uprooted to avoid damage. After harvesting, all yield parameters, including bulb weight, bulb diameter, number of cloves per bulb and yield were measured.

Germination percentage: The number of seedlings that emerged was counted daily until all cloves germinated successfully. Then, the time for 50%, 80%, and 100% germination for each plot was determined. Germination percentage was calculated based on the total number of cloves planted and the number of seedlings that emerged.

Germination percentage (%) = (Number of germinated cloves / Total number of cloves planted) × 100%

Plant height: The heights of each sample plant from each plot were measured at 30 DAP, 60 DAP, 90 DAP and 120 DAP to assess the progressive growth of garlic plants under different mulching treatments. The length from the soil surface to the tip of the mature leaf was measured for five sample plants. The average value was taken as the mean plant height (cm) for that treatment.

Leaf numbers: The number of leaves on each sample plant from each plot was measured at 30 DAP, 60 DAP, 90 DAP and 120 DAP. All fully expanded leaves that were green and functional were considered during counting. The senescent and newly developing leaves were excluded. The average number of leaves from the five plants represented the mean value for that treatment at each observation date.

Diameter of bulb: After harvesting, the diameter of each bulb was measured at its widest portion across the middle using a Vernier caliper for precise and accurate reading, expressed in centimeters. The mean bulb diameter for each plot was obtained by calculating the average of the five measured bulbs.

Number of cloves per bulb: After harvesting, bulbs from each sample plant were separated carefully into individual cloves. The total number of cloves present in each bulb was counted manually. The mean number of cloves per bulb for each plot was obtained by calculating the average value from the five sampled bulbs.

Total biomass and economic yield: Total biomass yield includes the total dry matter produced by a plant, including all above-ground and below-ground parts such as leaves, stems, bulbs and roots. Economic yield, however, includes only a portion of the plant that is useful or marketable, which includes only the bulb in the case of garlic. Both of these yields were measured using a digital weighing balance and expressed in kilograms (kg).

Weight of Bulb: After harvesting, the weight of bulbs of the samples was taken, and the average weight of bulbs per plant was calculated.

Soil moisture: The soil samples were collected after harvesting from each treatment plot using a soil auger, following the standard soil sampling technique. The subsamples were taken to the laboratory, where they were oven-dried at 105 °C ± 5 °C for 24 hours to remove all moisture content (FAO, 2023). The difference between the fresh (wet) and dry weights of the soil samples was used to determine the soil moisture percentage.

Soil Moisture Percentage (%) =Fresh Weight−Dry Weight/ Dry Weight×100%

Statistical analysis

The recorded data growth and yield parameters, along with soil moisture content, were first entered and tabulated using Microsoft Excel 2024. The data were then imported into RStudio (4.4.1) for statistical analysis. The data were subjected to Analysis of Variance (ANOVA) to determine the significance of treatment effects. Duncan's multiple range test (DMRT) was employed to detect variations in treatment means at the 5% level of significance.

RESULTS AND DISCUSSION

Germination percentage

Table 1 shows the significant effect of various mulching materials on the germination of garlic at various levels of significance. Rice straw mulch resulted in the fastest 50% germination within 6.75 days. It was statistically similar to wheat straw (7.00 days), Lentil straw (7days), and control (7.25 days), but significantly earlier than plastic mulch (9 days). However, for 80% germination, plastic mulch (9.50 days), wheat straw (9 days), Lentil straw (9.75 days) and rice straw (10.25 days) showed statistically similar results. Control plots took the longest time to reach 80% germination in 14.75 days. Similarly, 100% germination was achieved quickest in Lentil straw (12.00 days) and plastic mulch (12.25 days). Both Rice straw (13.75 days) and Wheat Straw (13.75 days) were identical in statistical values. The control treatment required significantly more time (16.50 days) to achieve complete germination. The fastest germination in organic mulches could be attributed to their ability to maintain adequate soil moisture while simultaneously allowing proper aeration and moderate soil temperature. These organic mulches reduce moisture loss without excessive heat accumulation beneath the mulch, which facilitate in enzymatic activity, water absorption, and sprout emergence. Khaskheli *et al.* (2021) also found superior performance of organic mulches on germination by accelerating the time of germination. Plastic mulch, though relatively delayed 50% germination, accelerated complete germination (12.25 days). This can be attributed to the creation of a stable soil microenvironment, improved moisture conservation and reduced environmental stress by plastic (Bhatta *et al.*, 2020; Hang *et al.*, 2024; Bohara *et al.*, 2025), leading to faster completion of germination once sprouting begins. The delayed germination in the control plot can be attributed to higher soil moisture loss, temperature fluctuations, and exposure to environmental stress. The superior performance of black plastic mulch and minimal performance of the control plot on crop germination were also noticed by Chaulagain *et al.* (2024).

Table 1. Effect of different mulching on germination percentage.

Treatment	Germination (%)		
	50% germination	80% germination	100% germination
Control	7.25[b]	14.75[a]	16.50[a]
Plastic	9.00[a]	9.50[b]	12.25[b]
Rice Straw	6.75[b]	10.25[b]	13.75[b]
Wheat Straw	7.00[b]	9.00[b]	13.75[b]
Lentil Straw	7.00[b]	9.75[b]	12.00[b]
Grand Mean	7.4	10.65	13.65
LSD	1.11	2.06	2.62
F-test	**	***	*
SEm (±)	0.36	0.66	0.85
CV (%)	9.79	12.56	12.45

Note: DAP: Days after Sowing, CV: Coefficient of variation, LSD: Least significant difference; Ns: Non-significant, *: Significant at 5% significance, **: Significant at 1% significance, ***: Significant at 0.1% significance, ns: non-significant and SEm: Standard error of mean.

Plant height

Table 2 shows that there was a significant effect of mulching on the height of the plant throughout the observation period at 0.1% level of significance ($p \leq 0.001$). At 30 DAP, Lentil straw recorded the maximum height in plants (29.33 cm), which was statistically at par with rice straw mulch (28.13 cm). Wheat straw (26.71 cm) and plastic (25.62 cm) followed them, and were at par with each other. At 60 DAP, Lentil straw mulch produced the tallest plants (46.60 cm), and was at par with rice straw (43.69 cm) and wheat straw (42.87 cm). However, at 90 DAP, plastic mulch resulted in the maximum plant height (71.40 cm), which was statistically at par with Lentil straw mulch (70.32 cm) and rice straw mulch (69.06 cm). Finally, at 120 DAP, maximum height was again observed in plastic mulch (68.13 cm), which was at par with Lentil straw (67.05 cm) and rice straw (65.88 cm). Wheat straw followed it with a height of 62.86 cm. The minimum height was observed in the control plot throughout the observation with 23.21 cm, 33.78 cm, 57.02 cm and 53.75 cm at 30 DAP, 60 DAP, 90 DAP and 120 DAP, respectively. A similar result was achieved by Bohara *et al.* (2025). Bhatta *et al.* (2020) claimed that the height increase in plastic mulch can be explained by its superior ability to retain moisture in the soil, high soil temperature, and the high absorption of nutrients. Plastic mulch also reduced evaporation loss and promoted a stable soil microclimate, which further enhanced the growth of roots, uptake of nutrients and cell elongation. These factors contribute to increased vegetative growth and plant height. Lentil straw also promoted plant height considerably, which could be due to gradual decomposition and release of nutrients, especially nitrogen. Nitrogen plays a critical role in vegetative growth by promoting chlorophyll synthesis and cell division in garlic (Kevlani *et al.*, 2023). The minimal height of plants in the control plots could be explained by the moisture stress, the increased variability of the temperature and the loss of nutrients because of the evaporation and leaching. The loss in height of the plant at 120 DAP, compared to 90 DAP, is explained by the senescence, which is the process of natural ageing of plants whereby old leaves become yellow and dry and finally die. Consequently, the leaves dry up and become no longer turgid, which adds to the reduction in the plant height (Bresson *et al.*, 2017). Moreover, minerals and carbohydrates are carried out of the leaves to the growing bulbs as the plant grows older. Such assimilated redistribution inhibits such additional leaf growth and may result in a decrease in the height of the plants (Schippers *et al.*, 2015).

Leaf number of garlic

There were no significant differences in mulching on the number of leaves at 30 DAP; however, significant differences at varied levels of significance were observed in later stages of observation (Table 3). At 30 DAP, though not significantly different, wheat straw recorded the maximum number of leaves (3.00), followed by Lentil straw (2.95), and control (2.85), while plastic mulch recorded the lowest number of leaves (2.75). At 60 DAP, the maximum number of leaves was recorded in Lentil straw (3.60), which was statistically at par with plastic mulch (3.25) and wheat straw (3.10). At 90 DAP, plastic mulch produced the maximum number of leaves (6.72), which was statistically at par with Lentil straw (6.45). Rice straw (6.05) and wheat straw (6.00), which were at par with each other, followed them. At the final observation at 120 DAP, plastic mulch recorded the highest number of leaves (5.83), which was at par with Lentil straw (5.56). Rice straw followed them with 5.16 leaves, which was at par with wheat straw (5.11). Throughout the observation period, the minimum number of leaves was observed in the control plot with 2.85, 3.00, 5.60 and 4.48 leaves at 30 DAP, 60 DAP, 90 DAP and 120 DAP, respectively. Similar results were achieved by Malik *et al.* (2025). The improved moisture conservation, stabilized soil microclimate, and enhanced nutrient availability by plastic mulch collectively promoted the vegetative growth of garlic, including its leaf numbers. Rai & Negi (2021) also stated that the greatest leaf numbers are found in the treatment providing a suitable microclimate and edaphic environment to the plant. Lentil straw also resulted in a higher number of leaves under this study. This could be associated with its gradual decomposition and release of essential nutrients, particularly nitrogen (Thonnissen *et al.*, 2000). Nitrogen released from the gradual decomposition of Lentil mulch leads to enhanced chlorophyll synthesis, cell division, and leaf initiation, which ultimately increases the number of leaves (Kevlani *et al.*, 2023). Similarly, rice straw and wheat straw mulching showed an intermediate number of leaves. Cao *et al.* (2021) mentioned that these straw mulches improve the Integrated Fertility Index of soil by altering the soil organic carbon content and microbial community diversity. The minimal leaf numbers observed in

Table 2. Effect of different mulching on plant height of garlic.

Treatments	Plants height (cm)			
	30 DAP	60 DAP	90 DAP	120 DAP
Control	23.21^{c}	33.78^{c}	57.02^{c}	53.75^{c}
Plastic	25.62^{bc}	41.56^{b}	71.40^{a}	68.13^{a}
Rice Straw	28.13^{ab}	43.69^{ab}	69.06^{ab}	65.88^{ab}
Wheat straw	26.71^{b}	42.87^{ab}	66.13^{b}	62.86^{b}
Lentil Straw	29.33^{a}	46.60^{a}	70.32^{ab}	67.05^{ab}
Grand Mean	26.60	41.70	66.78	63.53
LSD	1.59	3.22	4.18	4.15
F-test	***	***	***	***
SEm (±)	0.51	1.04	1.35	1.34
CV (%)	3.88	5.02	4.06	4.24

Note: DAP: Days after Sowing, CV: Coefficient of variation, LSD: Least significant difference; Ns: Non-significant, *: Significant at 5% significance, **: Significant at 1% significance, ***:;Significant at 0.1% significance, ns: non-significant and SEm: Standard error of mean.

Table 3. Effect of different mulching on number of leaves of garlic.

Treatments	Number of Leaves			
	30 DAP	60 DAP	90 DAP	120 DAP
Control	2.85	3.00^{b}	5.60^{b}	4.48^{c}
Plastic	2.75	3.25^{ab}	6.72^{a}	5.83^{a}
Rice Straw	2.50	2.85^{b}	6.05^{bc}	5.16^{b}
Wheat Straw	3.00	3.10^{ab}	6.00^{bc}	5.11^{bc}
Lentil Straw	2.95	3.60^{a}	6.45^{ab}	5.56^{ab}
Grand Mean	2.81	3.16	6.16	5.22
LSD	0.43	0.45	0.57	0.63
F-test	ns	*	**	**
SEm (±)	0.13	0.14	0.18	0.20
CV (%)	9.95	9.26	6.00	7.85

Note: DAP: Days after Sowing, CV: Coefficient of variation, LSD: Least significant difference; Ns: Non-significant, *: Significant at 5% significance, **: Significant at 1% significance, ***: Significant at 0.1% significance, ns: non-significant and SEm: Standard error of mean.

Table 4. Effect of different mulching on Bulb Diameter (BD), Number of Cloves (NC), Total Biomass Yield (TBY), Economical Yield (EY), Weight of Bulb (BW) and soil moisture (SM).

Treatment	BD	NC	TBY	EY	BW	SM
Control	3.39^{b}	11.72^{c}	10.70^{c}	7.67^{c}	13.76^{c}	13.43^{d}
Plastic	4.30^{a}	18.35^{a}	19.96^{a}	15.08^{a}	27.06^{a}	21.43^{a}
Rice Straw	3.87^{ab}	13.65^{bc}	16.49^{b}	11.57^{b}	20.77^{b}	16.75^{c}
Wheat Straw	3.52^{b}	12.42^{c}	16.52^{b}	11.68^{b}	20.96^{b}	15.53^{c}
Lentil Straw	4.30^{a}	15.85^{ab}	17.47^{ab}	13.77^{ab}	24.72^{ab}	19.51^{b}
Grand Mean	3.87	14.40	16.23	11.95	21.45	17.33
LSD	0.35	3.01	3.14	2.24	4.04	1.88
F– test	***	***	***	***	***	***
SEm (±)	0.11	0.83	1.02	0.72	1.31	0.61
CV (%)	5.95	11.53	12.58	12.20	12.22	7.04

Note: DAP: Days after Sowing, CV: Coefficient of variation, LSD: Least significant difference; Ns: Non-significant, *: Significant at 5% significance, **: Significant at 1% significance, ***: Significant at 0.1% significance, ns: non-significant and SEm: Standard error of mean.

control plots are due to higher moisture loss, greater temperature fluctuations, and limited nutrient availability. The slight reduction in leaf numbers from 120 DAP compared to 90 DAP is attributed to the onset of senescence, where older leaves begin to dry, and nutrients are translocated from leaves to the developing bulbs.

Bulb diameter

There was a significant effect of different mulching on bulb diameter at 0.1% level of significance ($p \leq 0.001$) (Table 4). The maximum bulb diameter was recorded in plastic Mulch and Lentil Straw (each with 4.30 cm). Rice Straw followed it (3.87 cm), which was at par with wheat straw (3.52 cm) and control (3.39 cm). The superior bulb diameter of garlic under plastic mulch is attributed to its role in facilitating stable soil microclimate and nutrient uptake. This further enhances photosynthesis and promotes the translocation of assimilates from leaves to bulbs, resulting in increased bulb development. Lentil straw also showed improved bulb diameter, due to its contribution to soil fertility through Lentil decomposition and nutrient release. Similar findings were achieved by Islam *et al.* (2007) and Yimer (2020).

Number of cloves

There was a significant effect of mulching on the number of cloves per bulb at 1% level of significance ($p \leq 0.01$) (Table 4). Plastic mulch recorded the maximum number of cloves (18.35), which was statistically at par with Lentil straw (15.85). Rice straw (13.65) followed it, which was at par with wheat straw (12.42) and control (11.72). Thus, the lowest number of cloves was recorded in the control. The superior number of cloves under plastic mulch is due to its better bulb development and differentiation of cloves. Lentil straw also exhibited a considerable number of cloves due to its influence on proper vegetative development and adequate nutrient availability (Silva *et al.*, 2021), particularly nitrogen, during the bulb initiation and formation stage. Adequate moisture and nutrient supply during this critical stage facilitates proper bulb formation and clove differentiation, resulting in an increased number of cloves per bulb. Similar findings were achieved by Malik *et al.* (2025) and Jamil *et al.* (2005), who mentioned increased number of cloves is attributed to the ability of mulch to maintain optimal soil conditions, which supports robust clove formation.

Weight of bulb, total biomass yield and economic yield

There was a significant effect of mulching on bulb weight at 0.1% level of significance ($p \leq 0.001$) (Table 4). Plastic mulch recorded the highest bulb weight (27.06 g), which was statistically at par with Lentil straw (24.72 g). Wheat Straw (20.96 g) and rice straw (20.77 g) followed them with statistically similar results. The lowest bulb weight was recorded in the control plot (13.76 g). Similarly, there was a significant effect of mulching on biological yield at 0.1% level of significance ($p \leq 0.001$) (Table 4). The maximum biological yield was recorded in plastic mulch (19.96 t/ha), which was at par with Lentil straw (17.47 t/ha). Wheat straw (16.52 t/ha) and rice straw (16.49 t/ha) followed them with statistically similar values. Minimum biological yield was observed in the control plot (10.70 t/ha). Likewise, Mulching had a significant effect on economic yield at 0.1% level of significance (p ≤ 0.001) (Table 4). The maximum economic yield was recorded in the plastic mulch (15.08 t/ha), which was at par with Lentil straw (13.77 t/ha). Wheat Straw (11.68 t/ha) and rice straw (11.57 t/ha) followed them with statistically similar results. The lowest economic yield was recorded in the control (7.67 t/ha). Similar results were achieved by Jamil *et al.* (2005), Bohara *et al.* (2025) and Malik *et al.* (2025). Reduced weed competition and improved utilization of growth resources under plastic mulch contribute to enhanced crop performance (Sanwa *et al.*, 2023). The significantly higher bulb weight, biomass yield and economic yield of garlic under plastic mulch are associated directly with the superior vegetative and yield-related parameters, including leaf numbers, plant height, bulb diameter, and clove number. The enhanced vegetative growth indicated improved photosynthetic capacity due to greater leaf area development (Liu *et al.*, 2010). Increased plant height and leaf production as a whole contributed to higher assimilate synthesis, which is subsequently translocated to the developing bulbs during the bulbing stage (Desta *et al.*, 2021). Besides, plastic mulch also facilitated effective soil microclimate and enhanced nutrient uptake by roots, supporting efficient dry matter accumulation in bulbs. This ultimately resulted in superior bulb weight and higher total and marketable yield. Likewise, comparable performance of Lentil straw mulch in terms of yield parameters is attributed to its decomposition, significantly enhancing soil fertility due to its relatively high nitrogen contents and relatively low C: N ratio in legume residue as compared with cereal residues (Kebede, 2021; Silva *et al.*, 2021). This promotes vigorous plant growth, increased leaf formation, and improved plant height (Meena *et al.*, 2018; Rajput *et al.*, 2024; Valenzuela, 2024). This enhanced vegetative growth led to increased photosynthate production and more efficient assimilate translocation to bulbs during bulb initiation and enlargement stages (Desta *et al.*, 2021). This consequently improved biomass accumulation and led to higher bulb weight and economic yield.

Rice Straw and wheat straw also produced higher bulb weight and yield, in comparison to the control, which is attributed to the ability of organic mulches in balancing soil temperature fluctuations and providing a more stable edaphic environment for the garlic roots. According to Yimer (2020), reduced nitrate leaching, enhanced soil physical characteristics, decreased erosion, organic matter provision, temperature and water retention regulation, improved nitrogen balance, nutrient cycling, and increased biological activity are all benefits of using organic mulches. In contrast, relatively lower vegetative growth in the bare soil resulted in its reduced bulb development and overall yield in control plots (Seifu *et al.*, 2017). Overall, each mulching material had its own role in conserving soil moisture, regulating temperatures for plant growth, suppressing the weeds, and increasing garlic yields compared to normal control conditions (Baten *et al.*, 1995; Karangiya *et al.*, 2022).

Soil moisture

Soil moisture content was significantly influenced by mulching at 0.1% level of significance (p ≤ 0.001) (Table 4). Plastic mulch recorded the highest soil moisture content (21.43%), followed by Lentil straw (19.51%). Rice straw (16.75%) and wheat straw (15.53%) produced statistically similar results. The lowest soil moisture content was observed in the control (13.43%). Similar results were obtained by Malik *et al.* (2025), who found black plastic mulch showing the highest moisture level, followed by other organic mulches. The highest moisture content in plastic mulch is attributed to its impermeable nature, which effectively reduces evaporation losses from the soil surface and conserves moisture for a longer period (Demo & Bogale, 2024; Zambrano *et al.*, 2024). Lentil straw, too, maintains higher moisture content, which could be due to its ability to cover the soil surface and reduce evaporative losses while simultaneously improving soil structure through gradual decomposition. Rice and straw mulch showed considerable moisture in comparison to the control due to their insulating effect on the soil (Liang *et al.*, 2025). Danish *et al.* (2020) also suggested that these organic mulches significantly enhance soil moisture conservation by minimizing water loss through evaporation and improving water infiltration.

Conclusion

This study demonstrated that mulching significantly influenced the growth, yield, and soil moisture content of garlic under the subtropical conditions of Khajura, Banke. Plastic mulch outperformed all other mulching materials on different growth and yield parameters, along with soil moisture content observed in the study. Lentil straw showed the quickest 100% germination and also demonstrated considerable performance in all observed parameters following plastic mulch. This has highlighted lentil straw mulch as a sustainable alternative due to its soil fertility improvement and moisture conservation benefits. Other organic mulches like rice straw and wheat straw showed moderate performance over the control plots. Therefore, based on this study, plastic mulch is the most effective practice for enhancing garlic productivity in Khajura, Banke and Lentil straw mulch is suggested as an environmentally sustainable option. The long-term effect on soil health, economic feasibility, and cost-benefit analysis of different mulching materials should be the focus of future researchers.

DECLARATIONS

Authors' contribution statement: Conceptualization: S.T. and N.P.; Methodology: S.T. and N.P.; Software and validation: S.T. and N.P.; Formal analysis: S.T. and N.P.; Investigation: S.T. and N.P.; Resources: S.T. and N.P.; Data curation: S.T. and N.P.; Writing-original draft preparation: S.T. and N.P.; Writing-review and editing: N.P.; Visualization: S.T. and N.P.; Supervision: S.T.; Project administration: S.T. and N.P. All authors have read and agreed to the published version of the manuscript.

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