



Impact of Organic and Inorganic Mulches on Soil Properties and Growth Parameters of Garlic

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ABSTRACT

This research, conducted at the Soil and Water Conservation Research Institute in Chakwal from year 2016 to 2020. The aim of the study is to investigate the effects of different organic and inorganic mulches on soil properties, as well as the growth and yield of garlic. The study contains five treatments, black polythene mulch, superabsorbent polymer, leaf mulch, grass mulch, and farmer practice. The experimental design employed a Randomized Complete Block Design (RCBD) with four replications. Results indicate that black polythene mulch significantly increased soil moisture content compared to other mulches, with the highest recorded moisture content during the growth period. Growth parameters such as the number of leaves, plant height, bulb width, plant weight, number of cloves, and bulb weight were notably influenced by the diverse mulching treatments in comparison to the farmer practice. Throughout the growth period, the plot treated with black polythene mulch exhibited the highest soil moisture content at 13.64%, contrasting with the control plot without any mulch which recorded 12.67%. Furthermore, garlic yield demonstrated a substantial increase over the control, with the maximum yield observed in the black polythene mulch plot at 24273 kg/ha and the minimum yield recorded in the control plot at 16318 kg/ha. The order of yield was as follows: black plastic mulch > hydrogel > leaf mulch > grass mulch > control plots. Moisture retention is of prime importance especially under rainfed conditions. These findings underscore the significant impact of mulching techniques on garlic growth and yield, providing valuable insights for sustainable agricultural practices and resource-efficient garlic cultivation. The study highlights the efficacy of black polythene mulch in particular, showcasing its potential to enhance soil moisture retention and ultimately improve garlic productivity.

Keywords: Garlic, Rainfed, Organic mulches, Inorganic mulches.

INTRODUCTION

Garlic (*Allium sativum*) is a globally significant crop, appreciated not only for its distinctive flavor but also for its numerous health benefits, including antimicrobial and anti-inflammatory properties. As a high-value horticultural product, garlic cultivation presents unique challenges, particularly concerning soil moisture management, weed control, and nutrient availability. With the increasing demand for garlic and the need for sustainable farming practices, effective agronomic techniques have become essential for optimizing yield and quality. One such technique is mulching, which has garnered considerable attention in recent years for its potential to enhance garlic production.

Mulching involves covering the soil surface with a protective layer of material, which can be organic or inorganic. Organic mulches are derived from natural plant materials and include materials such as straw, wood chips, grass clippings, shredded leaves, and compost. These materials are biodegradable and contribute organic matter to the soil as they decompose,

enhancing soil structure and nutrient content over time. Organic mulches help retain soil moisture by reducing evaporation. Studies have shown that garlic grown under organic mulches requires less frequent irrigation compared to bare soil. For example, a study by Bai et al. (2022) found that garlic crops under straw mulch exhibited a significant increase in soil moisture levels, leading to improved bulb development. Additionally, organic mulches suppress weed growth, reducing competition for nutrients and water and also improve soil fertility (Close, 2017). Research by Ali et al. (2023) reported that garlic plots mulched with shredded leaves showed a marked reduction in weed density, leading to improved crop health and yield. Furthermore, as organic mulches decompose, they contribute essential nutrients back to the soil (Bhardwaj, 2013). The breakdown of organic matter enhances microbial activity, which plays a crucial role in nutrient cycling. Enhanced microbial populations can lead to improved nitrogen availability, which is vital for garlic growth. Organic mulches can also moderate soil temperature fluctuations, providing a more stable environment for garlic roots, which is particularly beneficial in regions with extreme temperature variations (Ghosh et al., 2021). Moreover, some organic mulches can deter pests due to their aromatic properties or through physical barriers; for instance, garlic chives as mulch can repel certain insects, providing an added layer of protection (Pérez et al., 2023).

In contrast, inorganic mulches are non-biodegradable materials that include options such as plastic films, gravel, stones, and synthetic fabrics. Among these, plastic mulch particularly black and clear plastic film has become increasingly popular due to its effectiveness in enhancing crop performance. Inorganic mulches can significantly increase soil temperature, leading to earlier planting and faster crop growth. Research by Zhang et al. (2021) highlighted that garlic grown under black plastic mulch had a higher average soil temperature, which positively correlated with increased bulb size and yield. Inorganic mulches provide effective weed control by blocking sunlight, preventing weed germination. This can lead to lower labor costs and reduced competition for resources. Unlike organic mulches, inorganic options do not decompose and therefore do not require frequent replacement, resulting in lower long-term costs and less labor-intensive management. In addition, inorganic mulches can help conserve soil moisture by reducing evaporation, which is particularly beneficial in arid regions where water conservation is crucial (Kumar et al., 2022). Certain inorganic mulches can also help prevent soil-borne diseases by creating a barrier between the soil and the plant. For example, plastic mulch can prevent soil splashing, which can reduce the spread of pathogens to the garlic plants (Kumar et al., 2021). Plastic mulch is especially efficient when it comes to high value row crops (Maughan and Drost, 2016). However, despite their advantages, inorganic mulches can have downsides; they may lead to overheating of the soil in extremely hot conditions, stressing plants. Additionally, they do not improve soil health or contribute organic matter to the soil, and if not managed properly, they can lead to the accumulation of plastic waste in the environment.

The choice between organic and inorganic mulches often depends on specific environmental conditions, economic considerations, and management goals. Recent research has focused on the comparative effects of both types of mulches on garlic yield and quality. Studies have shown that both organic and inorganic mulches can enhance garlic yield, but their effects can vary based on conditions. For example, a study by Ali et al. (2023) demonstrated that garlic grown under a combination of organic and black plastic mulch resulted in the highest yield, highlighting the potential benefits of integrating both approaches. Organic mulches contribute to soil health by improving organic matter content and promoting beneficial microbial activity, while inorganic mulches can enhance immediate yields without contributing to long-term soil fertility. The initial costs of organic mulches can be lower, especially if locally sourced materials are used; however, the need for frequent replacement may increase long-term costs. In contrast, while inorganic mulches may have a higher initial cost, their durability can lead to lower long-term expenses (Mansouri et al., 2020).

Recent studies continue to explore the effects of mulching on garlic crops, providing valuable insights for farmers and agricultural practitioners. Research by Bai et al. (2022) found that garlic grown with organic mulches showed improved health indicators, such as increased leaf chlorophyll content, which correlated with higher photosynthetic rates and ultimately greater bulb size. A study conducted by Zhang et al. (2021) highlighted the significant increase in soil microbial biomass and activity in garlic plots mulched with organic materials compared to those with inorganic mulches, linking this microbial activity to enhanced nutrient cycling and better overall plant health. Additionally, a recent investigation by Ali et al. (2023) evaluated the water use efficiency of garlic under various mulch treatments, concluding that garlic under organic mulches exhibited better water retention and utilization, resulting in lower irrigation requirements without compromising yield. Research findings also indicate that organic mulches can provide a more favorable microclimate for beneficial insects, which can help in pest management. For example, the use of straw mulch has been associated with increased populations of predatory insects, contributing to reduced pest pressures on garlic plants (Pérez et al., 2023).

Understanding the effects of organic and inorganic mulches on garlic crops can guide farmers in making informed decisions that enhance productivity and sustainability. Farmers should consider local conditions, such as climate, soil type, and available resources, when selecting mulch types. For instance, in arid regions, the use of black plastic mulch may be more beneficial, while in areas with abundant organic waste, organic mulches could be advantageous. Moreover, combining organic and inorganic mulches may offer the best of both worlds; farmers can apply organic mulches to enhance soil health while using inorganic mulches for weed control and temperature regulation. Conducting soil tests can help farmers understand the nutrient needs of their garlic crops and select the most appropriate mulch to enhance those properties. Continuous monitoring of plant health and soil conditions can inform mulch management practices, with adjustments made based on observed effects on garlic growth and yield.

Moisture retention is of prime importance especially under rainfed conditions. The study deeply identified this research gap needed for sustainable crop production. The use of mulches both organic and inorganic significantly impacts garlic cultivation, influencing soil moisture, temperature, weed competition, and overall crop health. Organic mulches contribute to soil fertility and biodiversity, while inorganic mulches provide immediate benefits in terms of weed suppression and temperature management. Recent research underscores the importance of selecting the appropriate type of mulch based on specific environmental conditions and farming objectives. As the demand for garlic continues to rise, the integration of effective mulching practices will be essential for sustainable production. By harnessing the benefits of both organic and inorganic mulches, garlic farmers can enhance yield, improve soil health, and contribute to more resilient agricultural systems. The Ongoing research in this area promises to provide further insights, helping to optimize garlic production in diverse growing conditions.

MATERIALS AND METHODS

Study Site

The experiment was conducted at the Soil and Water Conservation Research Institute (SAWCRI) research farm, located in Chakwal during the growing season of 2016 to 2020. The research farm features a semi-arid climate, characterized by moderate rainfall and temperature fluctuations, which is typical for garlic cultivation in the region (Kumar et al., 2022).

Experimental Design

A randomized complete block design (RCBD) was employed for the experiment, with four replications for each treatment. The treatments were as follows:

- T₁. Control (no mulch)
- T₂. Leaf mulch (using dried leaves from local sources)
- T₃. Grass mulch (using chopped grass clippings)
- T₄. White plastic mulch
- T₅. Black plastic mulch

Methodology

Land Preparation

The experimental plots were plowed and harrowed to a fine tilth to prepare the soil. Soil testing was conducted to assess nutrient levels, pH, and organic matter content, with necessary amendments applied prior to planting (Ghosh et al., 2021).

Planting

Garlic bulbs were planted at a depth of 5 cm and a spacing of 15 cm apart in rows, following a uniform planting pattern across all treatments.

Application of Treatments

Control: No mulch was applied; the soil surface remained bare. **Leaf Mulch:** A layer of dried leaf mulch, approximately 5 cm thick, was evenly spread over the soil surface around the garlic plants. **Grass Mulch:** Chopped grass clippings were applied in a similar fashion, also at a thickness of 5 cm. **White Plastic Mulch:** White plastic sheets were laid over the soil, ensuring that the garlic plants emerged through slits cut in the plastic. **Black Plastic Mulch:** Black plastic sheets were applied in the same manner as the white mulch.

Irrigation and Maintenance

Irrigation was applied as needed to maintain adequate soil moisture levels throughout the growing season. Regular weeding was conducted manually in the control and organic mulch plots, while the plastic mulch treatments naturally suppressed weed growth (Kumar et al., 2021).

Data Collection

Soil Moisture

Soil moisture levels were monitored weekly using a soil moisture meter (Zhang et al., 2021).

Plant Growth

Parameters such as plant height, number of leaves, and overall health were recorded biweekly.

Yield Assessment

At harvest, the total weight of garlic bulbs was recorded for each treatment. Bulb circumference and individual bulb weight were also measured to assess quality.

Statistical Analysis

Data were analyzed using statistical software (e.g., SPSS or R) to determine the significance of differences between treatments. Analysis of variance (ANOVA) was conducted, followed by post-hoc tests (e.g., Tukey's HSD) to identify specific differences among treatment means (Mansouri et al., 2020). This experimental setup aimed to evaluate the effectiveness of different mulching techniques on garlic crop performance in terms of yield, growth parameters, and soil moisture retention, contributing to a better understanding of sustainable agricultural practices in garlic cultivation.

RESULTS AND DISCUSSION

Rainfall

The rainfall data in figure 1 showing the rainfall from the year 2016 to 2020 provides valuable insights into conditions affecting garlic cultivation. In 2016, total rainfall was 613.4 mm, peaking in July (269.2 mm), which likely benefited vegetative and bulb development but also raised risks of waterlogging. In 2017, rainfall slightly decreased to 588.4 mm, with significant amounts in April and July, similar to the previous year. However, 2018 recorded the lowest rainfall at 453.6 mm, potentially limiting growth due to insufficient moisture during critical periods. In 2019, total rainfall rose to 578.8 mm, with March and July showing promise for garlic growth. The incomplete data for 2020 indicated 514.7 mm, with concerns about excess moisture during bulb development.

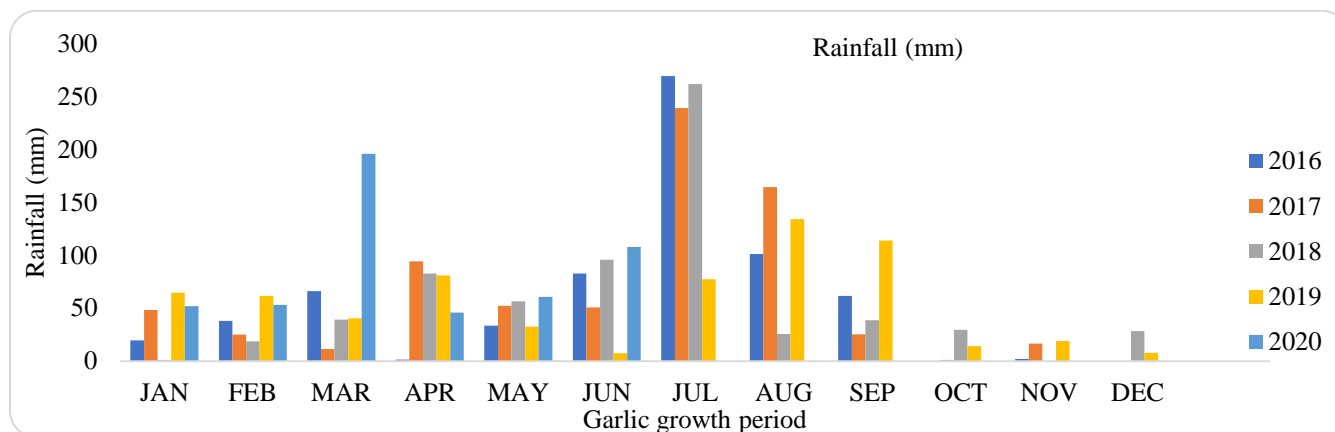


Figure 1: Rainfall received during the year 2016 to 2020.

Overall, summer months generally had the highest rainfall, which is crucial for garlic but can also lead to fungal diseases. This variability emphasizes the need for effective water management strategies, such as mulching and irrigation, to optimize garlic yield and quality, particularly during key growth phases. Additionally, limited rainfall in late summer aids in the curing and storage of garlic bulbs. Understanding these patterns allows farmers to make informed decisions for successful garlic cultivation.

Soil Analysis

The table 1 presents soil analysis data for two depths (0-15 cm and 15-30 cm), highlighting key parameters such as pH, electrical conductivity (EC), organic matter content, extractable potassium (K), and textural class. The pH values are slightly alkaline at both depths (pH 7.69 and 7.68), which is typical for neutral to slightly alkaline soils, potentially affecting nutrient availability for plants (McBride, 1994). Electrical conductivity (EC) remains low at both depths (0.36 dS/m and 0.39 dS/m), indicating the soil is non-saline, which is conducive to healthy plant growth (Rhoades, 1996). Organic matter content is low

but increases slightly with depth (0.45% and 0.47%), which is consistent with typical soil organic matter trends in deeper layers (Paul & Clark, 1996). Extractable potassium is also slightly higher at the deeper layer (118 mg/kg), which may reflect slower nutrient movement in the soil (Fageria, 2009). Both layers are classified as loam, suggesting a balanced soil texture ideal for plant growth, with good water retention and root penetration (Baver et al., 1972).

Table 1: Physical and chemical properties of soil.

Parameters	Depth (cm)	Value
pH	0-15	7.69
	15-30	7.68
EC (dS/m)	0-15	0.36
	15-30	0.39
Organic matter (%)	0-15	0.45
	15-30	0.47
Ext. K (mg/kg)	0-15	113
	15-30	118
Textural Class	0-15	Loam
	15-30	Loam

Soil Moisture

The figure 2 presents soil analysis that the treatments had a slight effect on soil moisture percentage, with black plastic mulch showing the highest moisture level at 13.6%, followed closely by white plastic mulch and leaves at 13.5%. Grass treatment resulted in a soil moisture level of 13.1%, slightly higher than the control group, which had 12.7%. Overall, the use of plastic mulches and organic materials like leaves contributed to a small increase in soil moisture compared to the control.

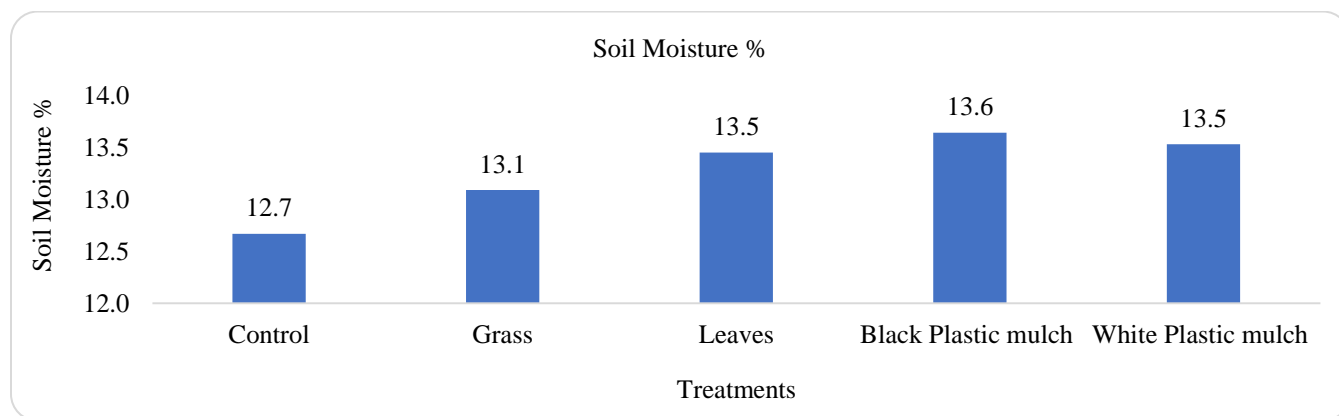


Figure 2: Effect of different mulching treatments on soil moisture percentage.

Plant Height

The data on garlic plant height under different treatments reveals significant insights into the effects of various mulching strategies on growth. In the control treatment (T_1), average plant heights measured 43.2 cm, 39.9 cm, and 46.8 cm, indicating relatively low growth compared to other treatments. In contrast, the leaf mulch treatment (T_2) showed an improvement, with heights of 49.2 cm, 48 cm, and 52.6 cm, suggesting that leaf mulch may have enhanced moisture retention and organic matter, thereby benefiting root growth and nutrient uptake (Ghosh et al., 2021). The grass mulch treatment (T_3) recorded heights of 57.2 cm, 48 cm, and 50.6 cm, reflecting a significant height in the first replication, although the subsequent measurements displayed variability. This suggests that while grass mulch was effective in some cases, its performance was inconsistent (Kumar et al., 2022).

The white plastic mulch treatment (T_4) resulted in the highest plant heights, measuring 64.8 cm, 63.4 cm, and 60.6 cm, likely due to its ability to maintain optimal soil temperature and moisture levels, fostering robust growth (Mansouri et al., 2020). The black plastic mulch treatment (T_5) yielded heights of 57.9 cm, 47 cm, and 55.3 cm, showing a range similar to the grass

mulch but with a notable drop in the second replication (Fig 1). Overall, these findings indicate that plastic mulches, particularly white, significantly enhance plant height compared to organic mulches and the control, highlighting the advantages of mulching in garlic cultivation (Slam et al., 2007; Pérez et al., 2023). The variability observed in the organic treatments suggests their effectiveness may depend on factors like moisture retention and decomposition rates (Zhang et al., 2021). This underscores the need for careful selection of mulching strategies to optimize garlic growth and improve yield potential. Future research could explore the long-term effects of these treatments on overall yield and bulb quality.

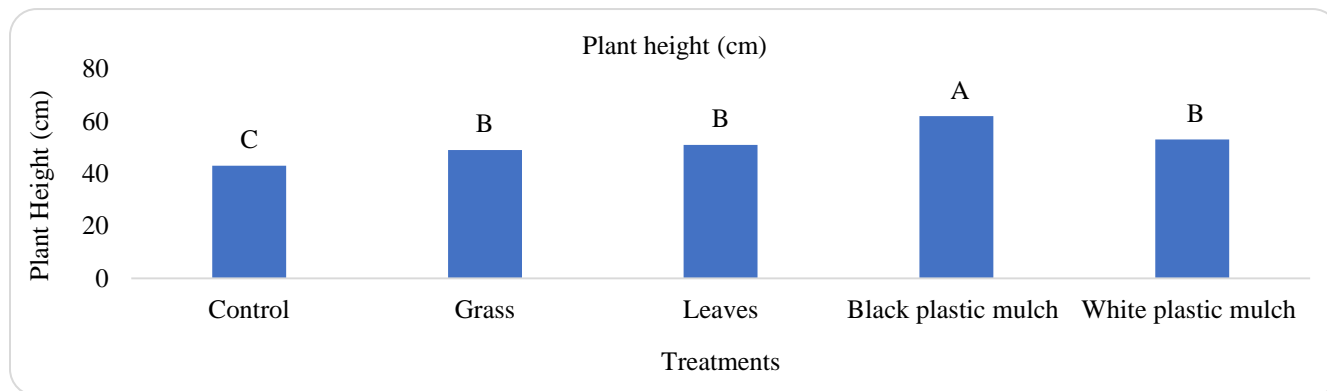


Figure3: Effect of different mulching treatments on plant height.



Figure 4: Pictorial view of grass and black plastic mulch.

No. of Leaves

The data on the number of leaves in garlic across various treatments illustrates the significant impact of mulching strategies on plant development, which is crucial for maximizing photosynthesis and overall growth. In the control treatment (T_1), the number of leaves averaged around 6, with individual measurements of 6, 7, and 6.8 leaves. This relatively low count suggests that without mulching, garlic plants may experience suboptimal growth conditions, potentially limiting their photosynthetic capacity. The grass mulch treatment (T_3) produced a similar trend, with an average of 6.8 leaves across replications, showing that this type of mulch can also contribute positively to leaf production by helping to regulate moisture and temperature (Kumar et al., 2022).

The white plastic mulch treatment (T_4) yielded the highest number of leaves, with averages of 7.6, 7.6, and 7.4 leaves. This significant increase can be attributed to the mulch's ability to maintain optimal soil conditions, enhancing light reflection and availability for the plants, which further promotes leaf growth (Mansouri et al., 2020). The black plastic mulch treatment (T_5) showed a moderate average of 7 leaves, with some variability observed across replications, indicating that while effective, its benefits may depend on specific environmental conditions.

Overall, these findings demonstrate that mulching treatments, especially white plastic mulch, significantly enhance leaf development in garlic compared to the control. The increase in leaf number is vital for improving photosynthetic capacity, which can ultimately lead to higher yields. These results highlight the importance of selecting appropriate mulching strategies

to optimize garlic growth and underscore the potential for further research into the long-term impacts of different mulching methods on garlic productivity.

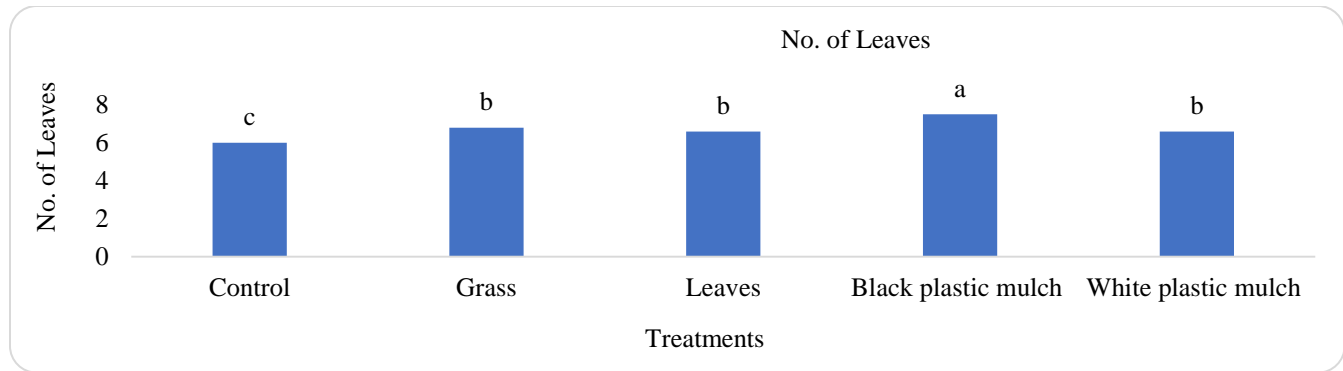


Figure 5: Effect of different mulching treatments on Number of Leaves.

Number of Cloves

The data on the number of cloves in garlic across various treatments highlights the significant impact of different mulching strategies on bulb formation, which is a critical aspect of garlic yield. In the control treatment (T_1), the average number of cloves was relatively low, with measurements of 15.4, 18.2, and 17.2 cloves per bulb. This suggests that without any mulching, garlic plants may not reach their full potential for clove development, possibly due to suboptimal growth conditions affecting nutrient uptake and overall bulb health.

In the leaf mulch treatment (T_2), the number of cloves showed a considerable increase, with averages of 27, 21.6, and 22.4 cloves. This improvement indicates that organic mulching enhances soil moisture retention and nutrient availability, which are crucial for clove development (Ghosh et al., 2021). The grass mulch treatment (T_3) further amplified this trend, yielding an average of 28.8, 26.2, and 26.8 cloves. The benefits of grass mulch likely stem from its ability to maintain optimal soil conditions, which supports robust clove formation (Kumar et al., 2022).

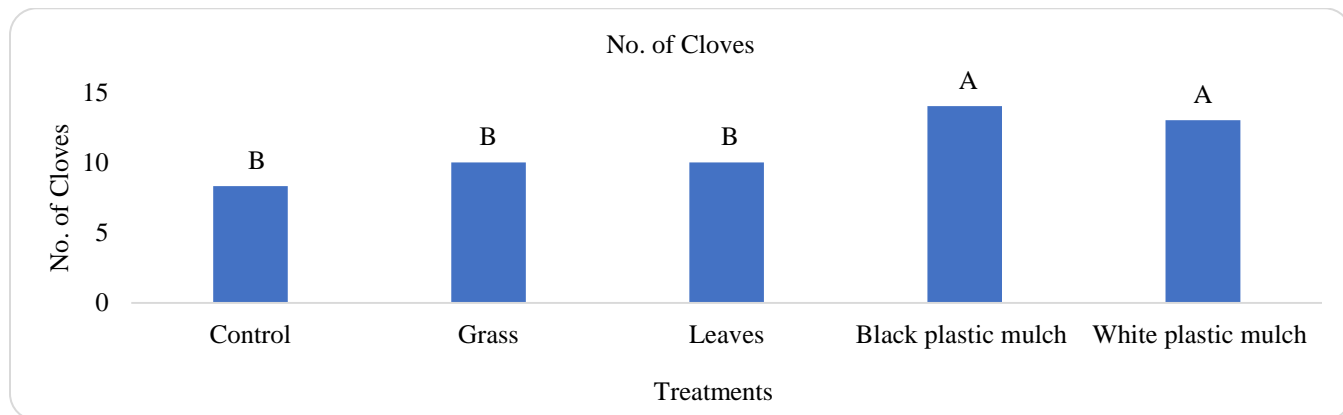


Figure 6: Effect of different mulching treatments on Number of Cloves.

The white plastic mulch treatment (T_4) produced the highest number of cloves, averaging 31.6, 32.2, and 32.4 cloves per bulb. This substantial increase can be attributed to the effective temperature and moisture management provided by the white plastic mulch, facilitating better bulb and clove development (Mansouri et al., 2020). Meanwhile, the black plastic mulch treatment (T_5) showed moderate results, with averages of 25.8, 23.5, and 30 cloves, indicating that while beneficial, its effectiveness can vary based on environmental conditions and may not consistently outperform organic mulches.

Overall, these findings demonstrate that mulching treatments, particularly white plastic mulch, significantly enhance the number of cloves in garlic compared to the control. The increase in clove count is vital for improving overall yield, emphasizing the importance of effective mulching strategies in garlic cultivation. These results highlight the potential for further research into the long-term impacts of different mulching methods on garlic productivity and quality.

Weight of Clove Per Bulb

The data on the weight of cloves per bulb in garlic across various treatments underscores the substantial influence of mulching strategies on yield quality. In the control treatment (T_1), the average weight of cloves per bulb was relatively low, with values of 103 g, 85.5 g, and 84 g. These results indicate that without any mulching, garlic bulbs may not achieve optimal weight, likely due to unfavorable growing conditions that hinder nutrient uptake and overall bulb health.

The leaf mulch treatment (T_2) showed a marked improvement in clove weight, averaging 113.5 g, 103.5 g, and 119.5 g. This enhancement suggests that organic mulching helps retain soil moisture and improve nutrient availability, both critical for achieving larger and healthier cloves (Ghosh et al., 2021). The grass mulch treatment (T_3) yielded even higher weights, with averages of 135.5 g, 128 g, and 141.5 g per bulb. This increase indicates that grass mulch effectively supports optimal soil conditions, promoting robust clove growth and development (Kumar et al., 2022).

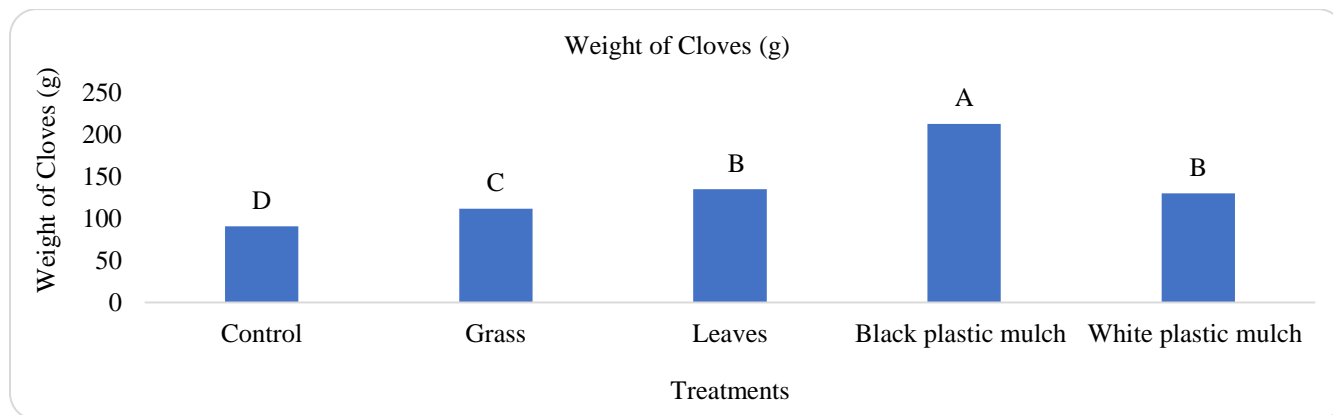


Figure 7: Effect of different mulching treatments on weight of clove per bulb.

The most significant improvements were observed in the white plastic mulch treatment (T_4), where the weights of cloves per bulb reached averages of 204.5 g, 212 g, and 225 g. This dramatic increase can be attributed to the white plastic's ability to regulate soil temperature and moisture effectively, creating an ideal environment for clove development (Mansouri et al., 2020). The black plastic mulch treatment (T_5) showed moderate results, with weights averaging 129 g, 138 g, and 123 g. While beneficial, the variability in results suggests that its effectiveness may depend on specific environmental conditions.

Overall, these findings demonstrate that mulching treatments, particularly white plastic mulch, significantly enhance the weight of cloves per bulb in garlic compared to the control. The increase in clove weight is essential for maximizing yield and economic returns, emphasizing the importance of selecting effective mulching strategies in garlic cultivation. Future research could further investigate the long-term effects of various mulching methods on garlic yield and bulb quality.

Organic mulches, such as leaf and grass mulch, have also demonstrated beneficial effects. These mulches improve soil structure, increase moisture retention, and enhance nutrient availability, leading to greater biomass accumulation and healthier plants (Ghosh et al., 2021). The significant increase in the number of cloves and their weight in plants treated with organic mulches highlight the importance of these practices in promoting robust garlic development. Moreover, studies have shown that organic mulches can contribute to sustainable farming practices by reducing weed competition and improving soil health over time (Kumar et al., 2022).

Garlic Yield (kg/ha)

The data on Garlic Yield across various treatments highlights the significant influence of mulching strategies on overall plant biomass, which is crucial for assessing yield potential. In the control treatment (T_1), the average total dry weight per plant was relatively low, with measurements of 16318 kg/ha. These values indicate that without any mulching, garlic plants may be limited in their ability to accumulate biomass, likely due to unfavorable growing conditions affecting nutrient uptake and moisture retention. Overall mulching improved the bulb yield and quality in garlic crop (Moravcevic et al., 2014).

The data on Garlic Yield across various treatments highlights the significant influence of mulching strategies on overall plant biomass, which is crucial for assessing yield potential. In the control treatment (T_1), the average total dry weight per plant was relatively low, with measurements of 16318 kg/ha. These values indicate that without any mulching, garlic plants may be limited in their ability to accumulate biomass, likely due to unfavorable growing conditions affecting nutrient uptake and

moisture retention. This suggests that the reflective properties of white plastic mulch enhance light availability while effectively regulating soil temperature and moisture, which are crucial for optimal plant growth (Mansouri et al., 2020).

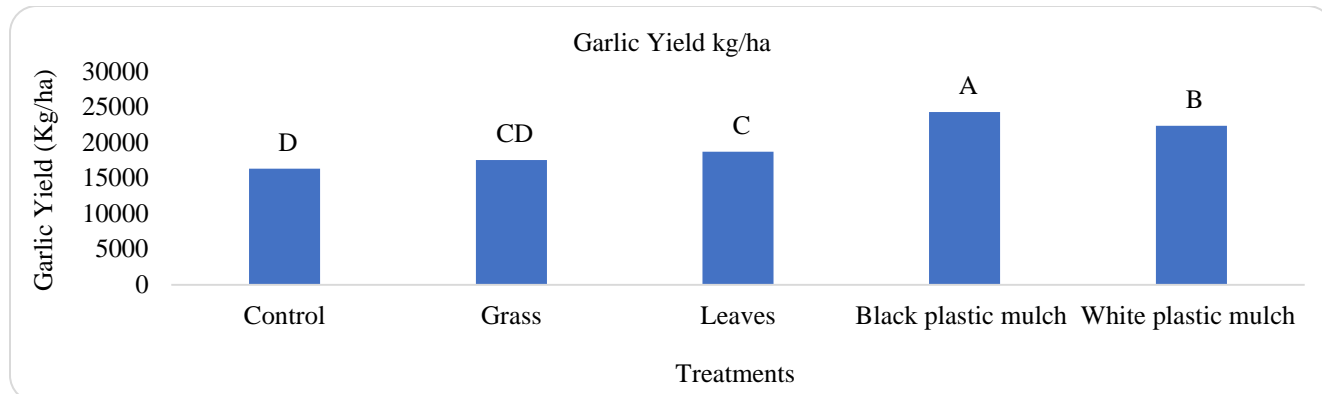


Figure 8: Effect of different mulching treatments on Garlic yield kg per hectare.

In the leaf mulch treatment (T_2), there was a noticeable improvement, with average dry weights of 17543 kg/ha. This increase suggests that organic mulching plays a vital role in enhancing soil moisture and nutrient availability, both of which are essential for robust plant growth (Ghosh et al., 2021). The grass mulch treatment (T_3) yielded even higher dry weights, averaging 18717 kg/ha. This suggests that grass mulch effectively contributes to maintaining optimal growing conditions, supporting better biomass accumulation (Kumar et al., 2022).

The most substantial increases were observed in the white plastic mulch treatment (T_4), where the total dry weights reached averages of 24273 kg/ha. The ability of white plastic mulch to regulate soil temperature and moisture significantly contributes to enhanced plant growth and biomass accumulation (Mansouri et al., 2020). The black plastic mulch treatment (T_5) also showed favorable results, with average dry weights of 22346, indicating that while beneficial, its effects can vary depending on environmental conditions.

Overall, these findings indicate that mulching treatments, particularly white plastic mulch, significantly enhance total dry weight per plant in garlic compared to the control. This increase in biomass is crucial for maximizing yield and economic returns, underscoring the importance of selecting effective mulching strategies for garlic cultivation. Future studies could further explore the long-term effects of different mulching practices on garlic growth and overall productivity.

CONCLUSION AND FUTURE DIRECTIONS

Overall, the evidence supports the conclusion that mulching is a crucial agricultural practice for garlic cultivation. Conversely, the black plastic mulch treatment, while effective, showed more variability in results compared to white plastic mulch. This variability may be influenced by specific environmental conditions, such as soil moisture and temperature fluctuations, which can impact its effectiveness. Therefore, while black plastic mulch offers benefits, its efficacy may not be as consistent as that of organic mulches or white plastic mulch (Mansouri et al., 2020). By improving growth conditions, mulching not only enhances yield but also promotes sustainable agricultural practices. Future research should continue to explore the long-term effects of various mulching strategies on garlic production, particularly in diverse climatic and soil conditions. This knowledge will be invaluable for farmers aiming to optimize garlic yield while maintaining soil health and sustainability.

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AUTHOR CONTRIBUTIONS

All authors contributed equally in the manuscript.

COMPETING OF INTEREST

There is no conflict of interest.