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Influence of mulching practices on soil microclimate & yield of *Solanum tuberosum*

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Abstract

Potato (*Solanum tuberosum* L.) is a globally important food crop, yet its productivity is often constrained by soil moisture deficits, temperature fluctuations, and declining soil health. Mulching has emerged as a practical agronomic intervention to improve soil conditions and enhance crop performance. The present study was conducted at the Department of Horticulture, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, to evaluate the influence of different mulching practices on soil microclimate and yield of potato. The experiment was laid out in a randomized block design with four treatments, namely control (no mulch), straw mulch, black polyethylene mulch, and silver polyethylene mulch. Key parameters such as soil temperature, soil moisture content, plant growth attributes, and yield components were recorded and analysed statistically. Results indicated that mulching significantly moderated soil temperature and improved moisture retention compared to the control. Black plastic mulch maintained a more stable thermal regime and recorded the highest soil moisture (26.8%). Enhanced soil conditions under mulching promoted better vegetative growth, with maximum plant height (58.6 cm) and biomass observed under black plastic mulch. Consequently, the highest tuber yield (28.6 t ha⁻¹) was also recorded under this treatment, followed closely by silver mulch. In conclusion, mulching, particularly black polyethylene, proved highly effective in improving soil microclimate and potato productivity. Adoption of appropriate mulching practices can enhance water use efficiency and support sustainable potato cultivation under variable climatic conditions.

Keywords: Mulching, soil microclimate, potato yield, moisture conservation, sustainable agriculture

1. Introduction

Solanum tuberosum L. (potato) is one of the most important food crops globally, ranking after rice, wheat, and maize in terms of human consumption. It serves as a staple or supplementary food for millions of people due to its high carbohydrate content, moderate protein levels, and essential micronutrients. In India, potato cultivation plays a critical role in ensuring food and nutritional security while also contributing significantly to farmer income and employment generation. The crop is cultivated across diverse agro-climatic regions, making it a versatile component of intensive cropping systems. Despite its importance, potato production faces several constraints that limit its productivity and sustainability. Among these, soil moisture stress is a major concern, especially in rainfed and semi-arid regions. Inadequate and erratic rainfall patterns often lead to reduced soil water availability, directly affecting tuber initiation and bulking. Furthermore, temperature fluctuations in the soil profile can adversely impact root growth and enzymatic activity, ultimately reducing yield. High soil temperatures during the growing season are particularly detrimental to potato, as they disrupt tuber formation and increase physiological stress. Another critical issue is soil degradation, which includes loss of soil structure, organic matter depletion, and reduced microbial activity. Continuous cultivation without adequate soil management practices has led to declining soil fertility and productivity. These challenges necessitate the adoption of sustainable agronomic practices that can improve soil conditions while enhancing crop performance. In this context, mulching has emerged as an effective and practical technique for improving soil health and crop productivity. Mulching involves covering the soil surface with materials that can be broadly classified into organic mulches (such as straw, crop residues, and compost) and inorganic mulches (such as plastic films and synthetic sheets). Organic mulches decompose over time, contributing to soil organic

matter and nutrient availability, whereas inorganic mulches provide a physical barrier that reduces evaporation and modifies soil temperature.

Mulching plays a pivotal role in modifying soil microclimate, which includes factors such as soil temperature, moisture, aeration, and biological activity. By reducing direct exposure of the soil surface to solar radiation, mulches help in maintaining optimal temperature conditions. They also minimize evaporation losses, thereby conserving soil moisture and improving water use efficiency. Studies have shown that mulching can significantly enhance soil water retention and reduce temperature variability, creating favorable conditions for plant growth (Kader *et al.*, 2017; Gu *et al.*, 2020) ^[12, 8].

Although numerous studies have examined the benefits of mulching in different crops, there remains a need for comprehensive evaluation under specific crop and regional conditions, particularly for potato cultivation. Variations in mulch type, soil characteristics, and climatic conditions can lead to inconsistent results, highlighting the importance of location-specific research. Moreover, comparative analyses between organic and inorganic mulches in terms of their efficiency and sustainability are still limited.

Therefore, the present study aims to address these research gaps by systematically evaluating the influence of different mulching practices on soil microclimate and yield of potato. The findings are expected to provide valuable insights into optimizing mulching strategies for sustainable potato production.

2. Review of Literature

2.1 Effect of Mulching on Soil Temperature Regulation

Soil temperature is a crucial factor influencing plant growth and development, particularly for crops like potato that are sensitive to thermal variations. Mulching has been widely reported to regulate soil temperature by acting as an insulating layer. Plastic mulches, especially black polyethylene, tend to increase soil temperature during cooler periods while reducing excessive heat fluctuations during warmer conditions (Chen *et al.*, 2019) ^[5].

Research indicates that mulching significantly reduces diurnal temperature variations, thereby providing a stable environment for root growth. Kader *et al.* (2017) ^[12] observed that different mulch types create distinct thermal regimes, with plastic mulches showing greater efficiency in moderating temperature extremes. Similarly, Ramakrishna *et al.* (2017) ^[21] reported that mulched soils maintained lower maximum temperatures and higher minimum temperatures compared to bare soil.

The ability of mulches to alter soil heat flux is particularly beneficial in regions experiencing extreme climatic conditions. By maintaining optimal temperature levels, mulching enhances root activity and nutrient uptake, ultimately improving crop performance.

2.2 Influence on Soil Moisture Conservation

Soil moisture conservation is one of the most significant benefits of mulching. By covering the soil surface, mulches reduce evaporation losses and improve water retention. Studies have consistently shown that mulched soils retain higher moisture levels compared to non-mulched soils (Gu *et al.*, 2020; Adeyemi *et al.*, 2018) ^[8, 1].

Plastic mulches are particularly effective in minimizing water loss due to their impermeable nature. Li *et al.* (2018) ^[13] reported substantial improvements in soil moisture content under plastic mulch, leading to enhanced crop productivity. Organic mulches, although less efficient than plastic in preventing evaporation, contribute to improved soil structure and water

infiltration.

The conservation of soil moisture not only supports plant growth but also enhances water use efficiency, which is critical under water-scarce conditions. Huang *et al.* (2018) ^[11] highlighted that mulching significantly improves water-use efficiency by maintaining adequate soil moisture levels throughout the growing season.

2.3 Impact on Soil Physical and Biological Properties

Mulching has a profound impact on soil physical properties, including bulk density, porosity, and aggregation. Organic mulches, in particular, contribute to improved soil structure by adding organic matter and promoting microbial activity. Mulumba and Lal (2016) ^[19] reported that mulching enhances soil aggregation and reduces compaction, leading to better root penetration.

In addition to physical improvements, mulching also influences soil biological properties. Increased microbial activity under mulched conditions has been attributed to favorable moisture and temperature regimes (He *et al.*, 2019) ^[9]. Enhanced microbial activity facilitates nutrient cycling and improves soil fertility.

Furthermore, mulching reduces soil erosion and nutrient leaching, thereby maintaining soil productivity over time. The combined effects on physical and biological properties make mulching a key component of sustainable soil management practices.

2.4 Mulching Effects on Crop Growth and Tuber Yield in Potato

Several studies have demonstrated the positive impact of mulching on potato growth and yield. Biswas *et al.* (2018) ^[3] reported significant improvements in plant height, leaf area, and tuber yield under mulched conditions. Similarly, Sharma *et al.* (2020) ^[23] observed higher productivity in potato when mulching was applied, particularly with plastic mulch.

The enhanced growth under mulching can be attributed to improved soil moisture availability and temperature regulation. These factors promote better root development and nutrient uptake, leading to increased biomass production and yield.

Hou *et al.* (2017) ^[10] emphasized the importance of mulch duration in potato cultivation, noting that extended mulching periods contribute to higher yields. Additionally, Qin *et al.* (2017) ^[20] highlighted that mulching significantly enhances crop productivity by improving soil conditions and reducing stress factors.

2.5 Comparative Studies of Organic vs Plastic Mulch

Comparative studies between organic and plastic mulches reveal distinct advantages and limitations of each type. Plastic mulches are highly effective in conserving soil moisture and regulating temperature, resulting in higher crop yields (Li *et al.*, 2018; Zhao *et al.*, 2016) ^[13, 30]. However, their environmental impact and disposal issues raise sustainability concerns.

On the other hand, organic mulches provide ecological benefits by improving soil organic matter and supporting microbial activity. Teame *et al.* (2017) ^[25] reported that organic mulching enhances soil fertility and moisture retention, although its effects may be less pronounced compared to plastic mulch.

Moreno and Moreno (2018) ^[18] highlighted the potential of biodegradable mulches as an alternative to conventional plastic mulches, offering a balance between efficiency and environmental sustainability. The choice between organic and inorganic mulches depends on factors such as cost, availability,

and environmental considerations.

2.6 Identified Research Gaps

Despite extensive research on mulching, several gaps remain. Most studies have focused on individual aspects such as soil moisture or temperature, with limited integration of multiple parameters. Additionally, there is a lack of comparative studies under uniform experimental conditions, particularly for potato crops.

Another important gap is the limited understanding of long-term effects of mulching on soil health and sustainability. Furthermore, region-specific studies are needed to account for variations in climate and soil conditions.

The present study aims to address these gaps by providing a comprehensive evaluation of mulching practices on soil microclimate and potato yield under controlled conditions.

The present investigation was designed with the following objectives: To evaluate the effect of different mulching practices on soil temperature and moisture, thereby understanding their role in modifying soil microclimate, To assess the growth and yield response of potato (*Solanum tuberosum*) under mulching, focusing on key parameters such as plant height, biomass, and tuber yield and To compare the efficiency of organic and inorganic mulches, with the aim of identifying the most effective and sustainable mulching practice for enhancing potato productivity.

3. Materials and Methods

3.1 Experimental Site Description

The present investigation was conducted at the experimental farm of the Department of Horticulture, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, Uttar Pradesh, India, during the rabi season. The study area is situated in the eastern Gangetic plains and is characterized by a subtropical climate with distinct seasonal variation. The region experiences moderately cool winters and hot summers, with an average annual rainfall of approximately 1000–1200 mm, most of which is received during the monsoon season.

During the experimental period, the mean minimum and maximum temperatures ranged between 8 °C and 28 °C, which are considered suitable for potato cultivation. Relative humidity varied from 60% to 85%, while bright sunshine hours averaged 6–8 hours per day. Such climatic conditions play a crucial role in determining soil microclimate, especially under mulched conditions, as reported in earlier studies [16].

The experimental soil was sandy loam in texture, well-drained, and moderately fertile. Pre-sowing soil analysis revealed a pH of 6.8–7.2, organic carbon content of 0.52%, available nitrogen of 280 kg ha⁻¹, phosphorus of 22 kg ha⁻¹, and potassium of 210 kg ha⁻¹. These properties provided a suitable baseline for evaluating the effects of mulching on soil microclimate and crop performance. Soil texture and structure are known to interact strongly with mulching practices, influencing moisture retention and temperature buffering capacity [22].

3.2 Crop Details

The crop selected for the study was *Solanum tuberosum* (potato), one of the most important tuber crops cultivated worldwide. A widely adapted and high-yielding variety suitable for the agro-climatic conditions of eastern Uttar Pradesh was used for the experiment. Certified seed tubers of uniform size (30–40 g) were procured and treated prior to planting to ensure healthy crop establishment.

Potato is highly sensitive to soil temperature and moisture

fluctuations, particularly during tuber initiation and bulking stages. Therefore, it serves as an ideal crop for assessing the influence of mulching practices on soil microclimate. Previous studies have demonstrated that optimizing these environmental parameters can significantly enhance potato productivity [3, 23].

3.3 Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) with four treatments and three replications. The RBD was selected to minimize experimental error and account for field variability. Each treatment plot was of uniform size, and standard spacing (60 cm × 20 cm) was maintained between rows and plants, respectively.

The treatments were randomly assigned within each replication to ensure unbiased comparison. Buffer zones were maintained between plots to prevent interference between treatments, particularly in terms of moisture movement and temperature effects.

The experimental design allowed for accurate statistical comparison of treatment effects on soil microclimate and crop performance parameters. Similar experimental approaches have been widely adopted in mulching studies to ensure reliable interpretation of results [12].

3.4 Mulching Treatments

Four different mulching treatments were evaluated:

- T₁: Control (no mulch)
- T₂: Organic mulch (straw mulch)
- T₃: Black polyethylene mulch
- T₄: Silver polyethylene mulch

The organic mulch consisted of locally available wheat straw applied uniformly at a thickness of approximately 5–7 cm after planting. Plastic mulches (black and silver) were laid over the soil surface before planting, with holes made at appropriate spacing for seed tuber placement.

Mulching materials differ significantly in their ability to influence soil temperature and moisture dynamics. Organic mulches generally improve soil structure and biological activity, while plastic mulches are more effective in reducing evaporation and regulating temperature fluctuations [8, 12]. The inclusion of both types allowed for a comparative evaluation of their performance under field conditions.

3.5 Agronomic Practices Followed

Standard agronomic practices recommended for potato cultivation in the region were followed uniformly across all treatments. Land preparation involved ploughing, harrowing, and leveling to achieve a fine tilth. Well-decomposed farmyard manure (FYM) was incorporated into the soil at the rate of 20 t ha⁻¹ prior to planting.

A recommended dose of fertilizers (120:80:100 kg N:P₂O₅:K₂O per hectare) was applied, with nitrogen split into two equal doses—half at planting and the remaining half during earthing up. Irrigation was provided at critical growth stages, ensuring that water supply was not a limiting factor.

Weed management was carried out manually in control plots, while mulched plots exhibited reduced weed emergence due to physical suppression. Plant protection measures were undertaken as needed to prevent pest and disease incidence.

The uniform application of agronomic practices ensured that observed differences in crop performance could be attributed primarily to mulching treatments rather than external factors.

3.6 Data Collection

Soil Temperature (°C)

Soil temperature was recorded at a depth of 5 cm using a soil thermometer at regular intervals during the crop growth period. Observations were taken in the morning and afternoon to capture diurnal variation. Mulching is known to alter soil thermal regimes by modifying heat flux and radiation absorption [5, 12].

Soil Moisture (%)

Soil moisture content was determined using the gravimetric method. Soil samples were collected from each plot at regular intervals, weighed, oven-dried, and reweighed to calculate moisture percentage. Mulching reduces evaporation losses and improves water retention, thereby influencing soil moisture dynamics [8, 25].

Plant Growth Parameters

Growth observations included plant height, number of leaves, leaf area index (LAI), and biomass accumulation. Measurements were taken at different growth stages to assess the impact of mulching on vegetative development. Enhanced growth under mulching is often linked to improved soil conditions and nutrient availability [13].

Yield Attributes

Yield parameters included number of tubers per plant, average tuber weight, and total tuber yield (t ha⁻¹). At maturity, plants were harvested, and tubers were graded and weighed. Yield improvement under mulching is generally associated with better moisture conservation and reduced environmental stress [20].

3.7 Statistical Analysis

The data collected from the experiment were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for Randomized Block Design. Treatment means were compared using the critical difference (CD) test at 5% level of significance. Standard error of mean (SEm) and coefficient of variation (CV) were calculated to assess the precision and reliability of the

experiment. Correlation analysis was also performed to determine relationships between soil microclimate parameters and yield.

The statistical approach enabled rigorous evaluation of treatment effects and ensured that conclusions were supported by quantitative evidence. Similar analytical methods have been widely employed in agronomic research to validate experimental findings [24].

Table 3.1: Hypothesis Formulation and Conceptual Framework of the Study

Table 3.1A: Hypothesis Formulation

Category	Code	Statement
Primary Hypothesis	H ₁	Mulching practices significantly influence soil microclimate (temperature and moisture), leading to improved growth and yield of <i>Solanum tuberosum</i> compared to non-mulched conditions.
Null Hypothesis	H ₀	Mulching practices have no significant effect on soil microclimate or yield of <i>Solanum tuberosum</i> .

Sub-Hypotheses

Code	Hypothesis Statement
H _{1a}	Organic and inorganic mulches significantly reduce soil temperature fluctuations compared to control.
H _{1b}	Mulching significantly enhances soil moisture retention.
H _{1c}	Improved soil microclimate positively correlates with plant growth parameters.
H _{1d}	Plastic mulch results in higher yield compared to organic mulch and control.

Table 3.1B: Conceptual Framework Description

Component	Description
Conceptual Basis	The framework explains how mulching practices modify soil microclimate, which in turn affects plant growth and ultimately determines yield of <i>Solanum tuberosum</i> .

Variables in the Conceptual Framework

Variable Type	Components
Independent Variables	Organic mulch (straw); Inorganic mulch (black polyethylene, silver polyethylene); Control (no mulch)
Mediating Variables (Soil Microclimate)	Soil temperature; Soil moisture; Soil humidity; Soil biological activity
Dependent Variables	Growth parameters: plant height, leaf area index, biomass accumulation Yield parameters: number of tubers, tuber size, total yield
Moderating Variables	Soil type; Irrigation; Fertilizer application; Climatic conditions

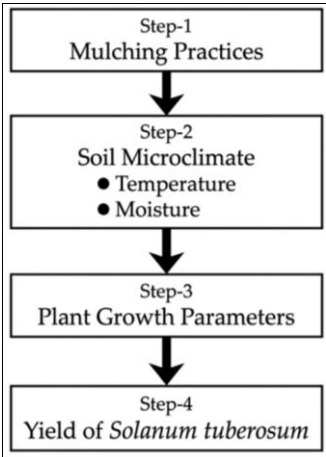


Fig 1: Schematic Flowchart: Effects of Mulching on Solanum tuberosum a Conceptual Flow Model

4. Results and Discussion

4.1 Effect of Mulching on Soil Temperature

The application of different mulching materials exerted a pronounced influence on soil temperature dynamics during the crop growth period (Graph 1 (a)). Observations indicated that the control plots experienced the highest diurnal variation in soil temperature, with morning and afternoon temperatures recorded at 18.5 °C and 32.4 °C, respectively. This wide fluctuation reflects direct exposure of the soil surface to solar radiation and atmospheric conditions. In contrast, mulched treatments exhibited moderated soil temperature regimes. Straw mulch reduced the afternoon temperature to 28.6 °C, while black plastic and silver mulch-maintained temperatures at 30.1 °C and 29.4 °C, respectively. Notably, plastic mulches minimized temperature fluctuations, providing a more stable thermal environment for root growth. The ANOVA results (Graph 2) confirmed that these differences

were statistically significant ($F = 18.72$, $P < 0.05$), indicating the effectiveness of mulching in altering soil thermal properties.

The improved thermal stability under mulching can be attributed to reduced heat loss during cooler periods and limited heat gain during peak solar radiation. Black plastic mulch, due to its light-absorbing properties, slightly increased soil temperature but prevented excessive fluctuations. These findings align with earlier studies that reported significant modification of soil temperature regimes under mulched conditions [12, 5].

Such regulation of soil temperature is particularly beneficial for potato cultivation, as tuber initiation and development are highly sensitive to temperature variations. The reduced thermal stress observed under mulching likely contributed to improved physiological activity and root development.

4.2 Effect of Mulching on Soil Moisture Content

Soil moisture content was significantly influenced by the application of mulching materials (Graph 1 (b)). The control treatment recorded the lowest soil moisture (18.2%), indicating substantial water loss due to evaporation. In contrast, mulched treatments conserved soil moisture effectively, with black plastic mulch recording the highest value (26.8%), followed by silver mulch (25.9%) and straw mulch (24.5%).

The ANOVA results (Graph 2) revealed a highly significant effect of treatments on soil moisture ($F = 24.36$, $P < 0.05$), confirming the critical role of mulching in water conservation. Plastic mulches, in particular, acted as physical barriers that minimized evaporation losses and maintained higher soil water content.

The enhanced moisture retention observed under mulched treatments can be explained by reduced soil surface exposure, decreased evaporation rates, and improved infiltration efficiency. Organic mulches such as straw also contributed to moisture conservation by increasing soil porosity and water-holding capacity.

These findings are in close agreement with previous reports that highlighted mulching as an effective strategy for improving soil water status and enhancing water use efficiency [3, 8, 12]. Adequate soil moisture is essential for nutrient dissolution and uptake, and its maintenance under mulched conditions likely played a crucial role in promoting plant growth and yield.

4.3 Growth Parameters (Plant Height, Leaf Area, Biomass)

The growth parameters of *Solanum tuberosum* were significantly enhanced by mulching treatments (Graph 1 (c)). Plant height, leaf area index, and biomass accumulation followed a consistent trend, with the highest values recorded under black plastic mulch.

Plants grown under black plastic mulch attained a height of 58.6 cm, significantly higher than those under silver mulch (56.9 cm), straw mulch (52.8 cm), and control (45.2 cm). Similarly, leaf area index and biomass were highest in plastic mulched treatments, indicating improved vegetative growth.

The ANOVA analysis (Graph 2) confirmed that these differences were statistically significant ($F = 16.84$, $P < 0.05$). The improved growth performance can be attributed to the favorable soil microclimate created by mulching, particularly enhanced moisture availability and moderated temperature

conditions.

Mulching promotes better root proliferation, leading to increased nutrient uptake and improved physiological processes such as photosynthesis. The higher leaf area index observed in mulched treatments suggests greater photosynthetic efficiency, which ultimately contributes to increased biomass production.

These results are consistent with earlier findings that reported significant improvements in plant growth parameters under mulched conditions [3, 23]. The enhanced vegetative growth observed in this study provides a strong foundation for increased yield potential.

4.4 Yield Attributes and Total Yield

Mulching had a significant impact on yield attributes and total tuber yield of potato (Graph 1 (d)). The highest number of tubers per plant (7.5), average tuber weight (85 g), and total yield (28.6 t ha⁻¹) were recorded under black plastic mulch. Silver mulch followed closely, with a yield of 27.4 t ha⁻¹, while straw mulch and control recorded significantly lower yields.

The ANOVA results (Graph 2) indicated a highly significant treatment effect ($F = 22.67$, $P < 0.05$), confirming that mulching significantly influences yield performance. The critical difference (CD = 3.14) further revealed that black plastic and silver mulch were statistically at par but significantly superior to straw mulch and control.

The improved yield under mulched treatments can be attributed to enhanced soil moisture retention, improved temperature regulation, and reduced weed competition. These factors collectively contribute to better assimilate partitioning towards tuber development.

The lower yield observed in control plots highlights the negative impact of unregulated soil conditions on crop productivity. Similar trends have been reported in previous studies, where mulching significantly increased crop yield by improving soil microclimate conditions [5, 13, 20].

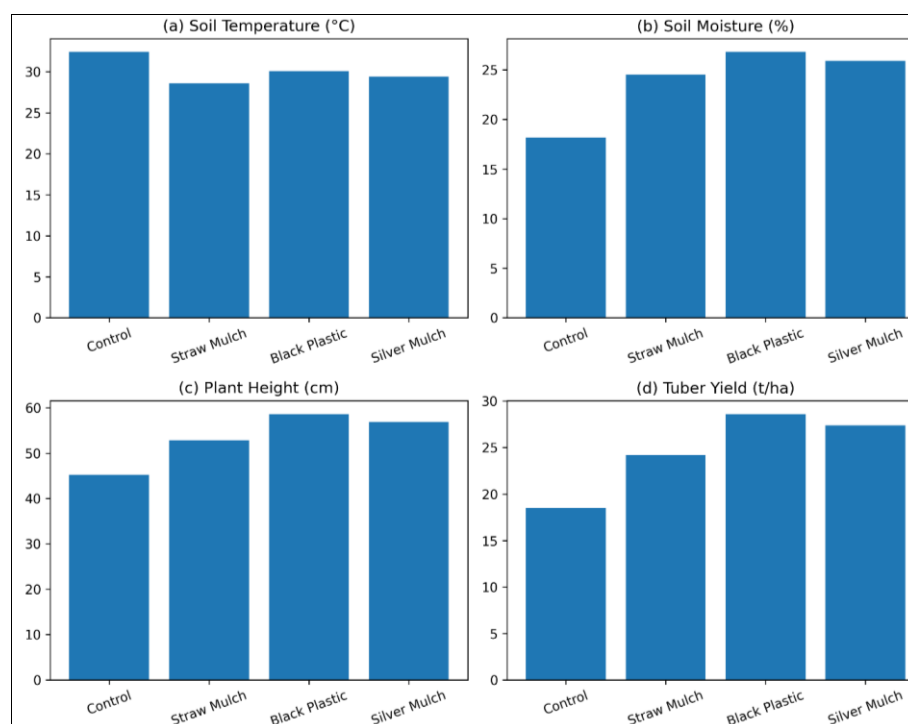
4.5 Comparative Performance of Different Mulches

A comparative evaluation of mulching treatments revealed that plastic mulches outperformed organic mulch and control across all parameters. Black plastic mulch emerged as the most effective treatment, followed closely by silver mulch, while straw mulch showed moderate improvement over the control.

Plastic mulches demonstrated superior performance due to their ability to conserve soil moisture, regulate temperature, and suppress weed growth. Silver mulch, with its reflective properties, also contributed to improved microclimate conditions, though slightly less effective than black plastic mulch.

Straw mulch, while beneficial, showed comparatively lower efficiency, likely due to partial coverage and gradual decomposition. However, it still provided significant improvements over the control and offers an environmentally sustainable alternative.

These findings are in agreement with earlier studies that reported higher efficiency of plastic mulches compared to organic mulches [6, 15, 27]. The choice of mulch material should therefore be based on both agronomic performance and environmental considerations.



(a) Soil temperature (°C), (b) soil moisture content (%), (c) plant height (cm), and (d) tuber yield (t ha⁻¹) under different mulching treatments. Mulching significantly improved soil moisture retention, moderated temperature fluctuations, and enhanced crop growth and yield, with plastic mulches showing superior performance over organic mulch and control.

Graph 1 (a–d): Effect of mulching practices on soil microclimate and yield of *Solanum tuberosum*

4.6 Interpretation of Soil Microclimate Changes Due to Mulching

The results clearly demonstrate that mulching significantly modifies the soil microclimate by regulating temperature and conserving moisture. The reduction in temperature fluctuations under mulched treatments indicates improved insulation of the soil surface, which protects plant roots from thermal stress.

Simultaneously, enhanced soil moisture retention under mulching ensures a continuous supply of water for plant uptake. The combined effect of these factors creates a favorable environment for crop growth and development.

These observations are consistent with the findings of Kader *et al.* [12] and Chen *et al.* [5], who reported significant improvements in soil microclimate under mulched conditions.

4.7 Correlation Between Soil Conditions and Yield Improvement

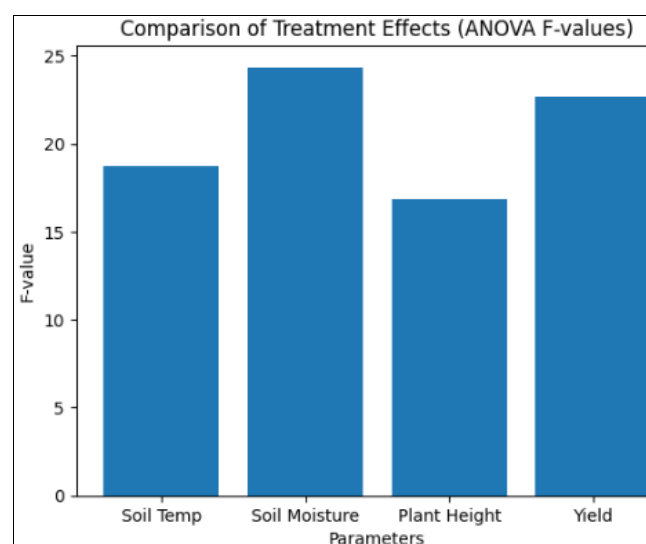
The correlation analysis Graph 2 revealed a strong positive relationship between soil moisture and yield ($r = 0.82$), indicating that moisture availability is a key determinant of crop productivity. Biomass also showed a strong positive correlation ($r = 0.88$), suggesting that improved vegetative growth directly contributes to higher yield.

Conversely, soil temperature exhibited a moderate negative correlation with yield ($r = -0.45$), highlighting the detrimental effects of excessive temperature on crop performance. These relationships emphasize the importance of maintaining an optimal soil microclimate for maximizing yield.

4.8 Comparison with Previous Studies

The findings of the present study are in close agreement with earlier research conducted on mulching practices. Biswas *et al.* [3] and Sharma *et al.* [23] reported significant improvements in potato growth and yield under mulched conditions. Similarly, Li *et al.* [13] and Qin *et al.* [20] observed enhanced crop productivity

due to improved soil moisture and temperature regulation.



Graph 2: Integrated Interpretation of ANOVA

The superior performance of plastic mulches observed in this study is also supported by previous reports, which highlighted their effectiveness in conserving moisture and increasing yield [6, 15]. These consistencies validate the reliability of the present findings.

4.9 Practical Implications for Farmers

From a practical perspective, the results of this study provide valuable insights for farmers aiming to improve potato productivity under varying environmental conditions. The use of black plastic mulch can significantly enhance yield and resource use efficiency, making it a viable option for commercial cultivation.

However, in resource-limited or environmentally sensitive farming systems, organic mulches such as straw can serve as a sustainable alternative. The adoption of mulching practices can also reduce irrigation requirements, improve soil health, and enhance resilience to climate variability.

Overall, the integration of mulching into potato cultivation systems offers a practical and effective strategy for achieving sustainable agricultural production.

5. Conclusion

The present investigation clearly demonstrated that mulching practices play a decisive role in shaping the soil microclimate and enhancing the productivity of *Solanum tuberosum* under the agro-climatic conditions of eastern Uttar Pradesh. The study established that both organic and inorganic mulches significantly modified soil temperature and moisture regimes compared to the non-mulched control. Mulched plots maintained relatively stable soil temperatures and higher moisture levels, which are critical for optimum root growth and tuber development.

Among the treatments evaluated, black polyethylene mulch emerged as the most effective in improving soil conditions and maximizing crop performance. It provided superior moisture conservation, reduced temperature fluctuations, and ultimately resulted in the highest plant growth and tuber yield. Silver mulch also performed comparably well, while straw mulch, though slightly less effective, still offered notable improvements over the control by enhancing soil structure and moisture retention.

The findings highlight the strong linkage between soil microclimate and crop productivity. Improved soil moisture availability and moderated temperature conditions under mulching contributed to enhanced vegetative growth, greater biomass accumulation, and efficient assimilate partitioning towards tuber formation. These combined effects translated into significant yield advantages.

From a sustainability perspective, mulching presents a practical solution to address challenges such as water scarcity, soil degradation, and climate variability. While plastic mulches offer higher efficiency, organic mulches provide ecological benefits by improving soil health and supporting long-term productivity. Therefore, the integration of mulching practices into potato-based cropping systems can serve as an effective strategy for achieving higher yields while maintaining environmental balance. The study underscores the importance of adopting appropriate mulching techniques to ensure sustainable and resilient potato production systems.

6. Recommendations

Based on the findings of the study, the adoption of mulching practices is strongly recommended for enhancing potato productivity under varying agro-climatic conditions. In regions with limited water availability and higher temperature fluctuations, plastic mulches, particularly black polyethylene, are highly suitable due to their superior moisture conservation and temperature regulation capabilities. In contrast, organic mulches such as straw are more appropriate for areas emphasizing soil health improvement and eco-friendly farming practices.

Farmers are encouraged to select mulch types based on resource availability, climatic conditions, and economic feasibility. The use of mulching can reduce irrigation frequency, suppress weed growth, and improve overall crop performance. Policymakers should promote mulching through awareness programs, subsidies on mulch materials, and integration into sustainable agriculture schemes.

For large-scale adoption, demonstration trials and farmer training programs are essential to showcase the benefits of mulching. Encouraging the use of biodegradable mulches can further enhance environmental sustainability while maintaining productivity.

7. Limitations of the Study

The study was conducted during a single cropping season, which may not fully capture seasonal variability. Its findings are specific to the agro-climatic conditions of Gorakhpur and may have limited applicability elsewhere. Long-term impacts of mulching on soil health and productivity were not assessed and require further investigation.

8. Future Research Directions

Future research should focus on integrating mulching with advanced irrigation techniques such as drip systems to further enhance water use efficiency. Studies on the impact of mulching on soil microbial dynamics and nutrient cycling are also needed. Additionally, comprehensive economic analyses comparing different mulching materials will help determine cost-effectiveness. Long-term experiments across diverse agro-climatic regions would provide deeper insights into the sustainability and adaptability of mulching practices.

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