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Effects of Mulching on Soil Temperature Regulation and Its Implications for Crop Growth in Ethiopia

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Abstract

Mulching has been recognized as a beneficial agricultural practice for centuries, with its effects on soil temperature and moisture retention being of particular importance. Mulching has significant effects on soil temperature regulation and its implications for crop growth. The investigation of the effects of mulching on soil temperature regulation and its implications for crop growth globally, in Africa, and specifically in Ethiopia has yielded valuable insights. Across diverse agro-ecological zones, mulching has proven to be a versatile and effective practice for moderating soil temperature, thereby influencing crop growth. Mulching had a pronounced effect in mitigating the extremes of soil temperature, especially during periods of heightened temperature variability mulching with crop residues increased soil temperature and improved soil moisture retention, which had positive effects on crop growth and yield. Findings globally indicate that organic mulches, such as crop residues, contribute to improved soil structure and moisture retention, creating a conducive environment for optimal plant development. In Africa, specifically in Ethiopia, studies have demonstrated the positive impact of mulching on crops like tomatoes and barley, emphasizing the need to consider local conditions and materials for successful implementation. The adoption of best practices, regional adaptations, and supportive policies emerges as a key strategy for maximizing the benefits of mulching on soil temperature regulation and crop growth.

Keywords: Crop Growth; Nutrient Dynamics; Mulching; Yield Variations

Introduction

Soil temperature regulation is a pivotal factor influencing the growth and development of crops, and it plays a crucial role in determining agricultural productivity [1]. Temperature profoundly affects various soil processes, including microbial activity, nutrient availability, and biochemical reactions [2]. Moreover, the germination, emergence, and metabolic activity of plants are intricately linked to the thermal conditions of the soil [3]. The need for maintaining optimal soil temperatures is universally acknowledged in the realm of agriculture [4]. Understanding and managing soil temperature is of paramount importance due to its direct impact on plant physiological processes [5]. Soil temperature influences seed germination rates, root development, and nutrient uptake by plants [6]. Moreover, temperature fluctuations can affect soil microbial communities, with consequences for nutrient cycling and organic matter decomposition [7]. As global climates undergo changes, the need to mitigate the adverse effects of temperature extremes on agriculture becomes increasingly urgent [8]. In a global context, the importance of soil temperature regulation extends across diverse agro-

ecological zones [4]. Regions with variable climates, from temperate to tropical, face unique challenges in managing soil temperatures to optimize crop growth [9]. Mulching, as a sustainable agricultural practice, has garnered attention for its potential to modulate soil temperature dynamics [10].

Global studies, such as the meta-analysis conducted by [11], underscore the significant role of soil organic matter the very component affected by mulching in influencing soil temperature and, consequently, crop yields. As the demand for food production intensifies to feed the growing global population, understanding how mulching practices impact soil temperature becomes essential for sustainable and resilient agricultural systems [12]. In Africa, where agriculture is a cornerstone of livelihoods, the relevance of soil temperature regulation is accentuated by diverse agro-ecological conditions [13]. The continent experiences a range of climates, from arid to humid, and faces unique challenges such as water scarcity, soil degradation, and the impacts of climate change [14]. Mulching practices, deeply rooted in African farming traditions, offer a promising avenue for addressing these challenges [15]. African agriculture has a rich history of mulching with locally available materials, such as crop residues and organic matter [16]. Studies conducted in African contexts, such as the research by Malamba B [17] in Botswana, provide insights into the benefits of mulching for soil temperature moderation and its positive implications for crop growth. Mulching not only conserves soil moisture but also protects against temperature extremes, making it a valuable tool for enhancing agricultural resilience [18]. In Ethiopia, a country characterized by diverse agro-ecological zones, the importance of soil temperature regulation is accentuated by the varying climates and cropping patterns [19].

Mulching practices, deeply intertwined with traditional farming systems, have been utilized by farmers for generations [20]. The country's agriculture faces challenges such as soil erosion, water scarcity, and unpredictable weather patterns, making the optimization of soil temperature through mulching a critical consideration [21]. Studies conducted in Ethiopia, such as those by Jelde A, et al. [22] on the impact of wheat straw mulch; demonstrate the tangible benefits of mulching for soil temperature regulation and its subsequent effects on crop growth. By exploring the specificities of mulching practices in Ethiopian agriculture, this research aims to contribute valuable insights that can inform sustainable and context-specific soil management strategies. Mulching has significant effects on soil temperature regulation and its implications for crop growth [23]. It has been found that straw mulching can have a heat insulation effect, keeping the ground temperature low during low-temperature periods and higher during high-temperature periods, which can affect crop emergence, growth, and yield [24]. Soil mulching, whether with plastic film or straw, has been shown to reduce evaporation and regulate soil temperature, leading to improved crop growth and yield [25]. Different mulching measures, such as jujube branches mulching and white clover planting, have been found to control soil temperature and moisture, resulting in enhanced jujube growth [26]. Additionally, the development of biodegradable and radiative cooling mulch has shown promising results in reducing soil moisture evaporation, improving plant growth, and alleviating agricultural water scarcity in hot seasons [27]. Overall, mulching plays a crucial role in regulating soil temperature and has positive implications for crop growth and yield.

General Objective

- The general objective of this paper is to examine the effects of mulching on soil temperature regulation and its implications for crop growth in Ethiopia.

Specific Objectives

- Investigate mulching practices in Ethiopian agriculture and their impact on soil temperature regulation.
- Understand the implications of mulching on crop growth in the context of Ethiopian agriculture.
- Explore the relationship between mulching and nutrient availability in the soil and its influence on crop nutrient uptake.
- Identify crop-specific responses to mulching practices through case studies.
- Provide recommendations for sustainable mulching practices that optimize soil temperature regulation and crop growth.

Discussion

Historical Overview of Mulching

Mulching has been recognized as a beneficial agricultural practice for centuries, with its effects on soil temperature and moisture retention being of particular importance. Previous studies have consistently shown that mulching can influence soil temperature by increasing it and improving moisture retention [28]. This has been observed globally, in Africa, and specifically in Ethiopia, highlighting the importance of mulching as a sustainable agricultural practice for improving soil conditions and crop productivity. In a global context, research by Kreyling J, et al. [29] demonstrated that mulching can have varying effects on soil temperature depending on the type of mulch material used and environmental conditions. This suggests that the historical use of mulching in different regions around the world may have been influenced by local environmental factors and the availability of specific mulch materials.

In Africa, a study by Mupangwa W, et al. [30] highlighted the importance of mulching in mitigating the effects of climate change on soil temperature and moisture. This suggests that mulching has been historically used as a climate adaptation strategy in African agriculture, with the potential to regulate soil temperature and moisture in the face of changing environmental conditions. In Ethiopia, a study by Alemu D, et al. [31] showed that mulching with crop residues can help to regulate soil temperature and reduce moisture loss, which is particularly important in the context of increasing temperatures and unpredictable rainfall patterns. This suggests that mulching has been historically used in Ethiopian agriculture to address specific challenges related to soil temperature and moisture retention. Overall, historical evidence from previous studies supports the idea that mulching has been used globally, in Africa, and specifically in Ethiopia, as a sustainable agricultural practice for improving soil conditions and crop productivity. Further research is needed to explore the specific historical use of different types of mulch materials and environmental conditions in different regions around the world.

Previous Studies on Mulching and Soil Temperature Regulation

Importance of Soil Temperature Regulation: Previous studies have shown that mulching can significantly influence soil temperature. A study conducted in the United States by Sainju UM, et al. [32] found that mulching with crop residues increased soil temperature compared to bare soil. Similarly, a study in Africa by Nyamangara J, et al. [33] showed that mulching with crop residues increased soil temperature and improved soil moisture retention. In Ethiopia, a study by Adimassu Z, et al. [34] also found that mulching with crop residues increased soil temperature and improved soil moisture retention, which had positive effects on crop growth and yield. In a global context, research by Kreyling J, et al. [29] demonstrated that mulching can have varying effects on soil temperature depending on the type of mulch material used and environmental conditions. In Africa, a study by Mupangwa W, et al. [30] highlighted the importance of mulching in mitigating the effects of climate change on soil temperature and moisture. In Ethiopia, a study by Ayano A, et al. [35] showed that mulching with crop residues can help to regulate soil temperature and reduce moisture loss, which is particularly important in the context of increasing temperatures and unpredictable rainfall patterns.

Soil temperature regulation is a critical aspect of agricultural ecosystems, directly influencing plant growth, nutrient availability, and overall soil health [36]. The significance of maintaining optimal soil temperatures has garnered attention globally, with researchers exploring various strategies to mitigate temperature extremes and enhance agricultural productivity [2]. As agriculture faces the challenges posed by climate change and shifting weather patterns, understanding the role of mulching in soil temperature regulation has become imperative for sustainable and resilient farming practices [37].

Effects of Mulching on Soil Temperature

Temporal Variations:

Seasonal Changes: Mulching has been identified as a valuable tool for moderating soil temperature across different seasons, with significant implications for crop growth [38]. In a global context, research conducted by Zhao X, et al. [39] highlights how mulching influences soil temperature dynamics throughout the year. The study underscores the capacity of mulching materials to act as insulating layers, mitigating temperature extremes and providing a more stable environment for plant roots. In African agriculture, where the impact of seasonal variations is particularly pronounced, mulching has proven effective in ameliorating the effects of temperature fluctuations. Tesfaye T, et al. [40] conducted experiments in the central highlands of Ethiopia, revealing that plastic mulch not only regulated soil temperature but also exhibited varying effects across different seasons. The study demonstrated the adaptability of mulching practices to the seasonal nuances of African agroecosystems. In Ethiopia, characterized by diverse agroecological zones, the temporal variations in soil temperature pose unique challenges to farmers [41]. Tadesse T, et al. [28] investigated the impact of wheat straw mulch on soil temperature in the northwestern Ethiopian highlands. The results indicated that mulching had a pronounced effect in mitigating the extremes of soil temperature, especially during periods of heightened temperature variability.

Day-Night Temperature Dynamics

The day-night temperature dynamics influence plant metabolic processes and growth. Globally, studies by Ouellet E, et al. [42] have shown that mulching, especially with plastic materials, can moderate day-night temperature fluctuations. The thermal buffering provided by mulch layers creates a more favorable microclimate for crops, ensuring that daytime warmth is retained during cooler nights [43]. In African agriculture, the day-night temperature dynamics are crucial for understanding the adaptability of crops to local conditions [44]. Mokgalabone TT [45] Study in Ethiopia demonstrated that plastic mulch contributed to maintaining optimal day-night temperatures for tomato cultivation. Ethiopian agriculture, with its diverse landscapes, benefits from the day-night temperature regulation provided by mulching practices [46]. Tadesse T, et al. [28] observed that wheat straw mulch significantly reduced day-night temperature differentials, creating a more stable thermal environment for crops. This contributes to improved plant

physiological processes and ultimately enhances crop productivity.

Spatial Variations

Within-Plot Variability: Mulching influences spatial variations in soil temperature within agricultural plots, impacting the microenvironments where crops grow. Globally, studies such as those by Zhao X, et al. [39] emphasize that mulching materials create a homogenizing effect, reducing spatial variability in soil temperature. This has implications for ensuring uniform crop development and yield. In African agriculture, where field variability is often pronounced, mulching practices play a crucial role in minimizing within-plot temperature variations. Assefa S, et al. [47] Observed that plastic mulch contributed to reducing spatial heterogeneity in soil temperature, fostering more consistent growing conditions for tomatoes in Ethiopian highlands. Ethiopian agriculture, characterized by diverse topographies, benefits from the homogenizing effect of mulching on soil temperature [28]. Found that wheat straw mulch significantly decreased within-plot temperature variability, providing a more uniform thermal environment for crops. This has practical implications for optimizing land use and ensuring consistent crop performance.

Comparisons between Mulch Types

Different mulching materials exhibit varying effects on soil temperature, and the choice of mulch type becomes a critical consideration for farmers. Globally, the study by Ouellet E, et al. [42] compared the effects of plastic mulch with other materials, demonstrating that plastic mulch had distinctive impacts on soil temperature regulation. Such comparative analyses contribute to understanding the relative effectiveness of mulching materials. In African agriculture, where resource availability and local practices influence mulch choices, understanding the comparative effects of different mulch types is essential. Assefa S, et al. [47] compared the performance of plastic mulch with other locally available materials, providing insights into the suitability of different mulches for soil temperature regulation in Ethiopian highlands. In Ethiopia, the comparison between mulch types is pertinent for optimizing agricultural practices. Tadesse T, et al. [28] Explored the impact of wheat straw mulch, shedding light on its efficacy compared to other potential mulching materials. This knowledge is valuable for Ethiopian farmers seeking context-specific solutions for soil temperature management.

The Effects of Mulching on Crop Growth: Implications and Nutrient Dynamics

Crop-Specific Responses:

Case Studies with Specific Crops: The impact of mulching on crop growth is inherently crop-specific, influenced by the unique physiological characteristics and requirements of each plant species [48]. Globally, comprehensive case studies have explored the crop-specific responses to mulching practices. Zhao X, et al. [39] conducted a meta-analysis that encompassed diverse crops, revealing varying degrees of sensitivity to mulching effects. The study emphasized the need for considering specific crops in assessing the implications of mulching on growth. In the African context, where agriculture sustains livelihoods across a myriad of crops, Assefa S, et al. [47] conducted case studies focusing on tomato cultivation in the central highlands of Ethiopia. The research demonstrated that plastic mulch significantly influenced the growth and yield of tomatoes. Understanding these crop-specific responses is crucial for tailoring mulching practices to the specific needs of African crops. In Ethiopia, where agroecological diversity influences crop cultivation, Tadesse T, et al. [28] conducted case studies with barley in the northwestern highlands. The research showcased the positive impact of wheat straw mulch on barley growth and yield. These case studies provide valuable insights into how mulching practices can be optimized for specific crops in Ethiopian agricultural systems.

Growth Patterns and Yield Variations: The growth patterns and yield variations resulting from mulching practices are significant considerations in understanding the implications for crop growth [49]. Globally, studies such as those by Ouellet E, et al. [42] have observed distinct growth patterns and yield variations in crops under different mulching regimes. The research highlighted the need to tailor mulching practices to specific crops to optimize growth and yield. In African agriculture, where subsistence farming often relies on diverse crops, understanding growth patterns and yield variations is essential. Assefa S, et al. [47] found that plastic mulch positively influenced the growth patterns of tomatoes, resulting in increased yields. These insights contribute to the development of sustainable and context-specific mulching strategies in Africa. In the Ethiopian context, Tadesse T, et al. [28] observed growth patterns and yield variations in barley influenced by wheat straw mulch. The study indicated that mulching not only improved growth but also contributed to more consistent yields. These findings underscore the potential of mulching to address yield variations and enhance overall crop productivity in Ethiopian agriculture.

Nutrient Availability

Influence of Soil Temperature on Nutrient Release: The influence of mulching on nutrient availability is a critical aspect of its implications for crop growth. Globally, Zhao X, et al. [39] highlighted the role of mulching in regulating soil temperature, which, in turn, influences nutrient release from organic matter. The meta-analysis indicated that the positive correlation between soil organic matter and crop yields is mediated by soil temperature dynamics. In African

agriculture, where nutrient management is crucial for sustainable farming, Assefa S, et al. [47] investigated the influence of plastic mulch on soil temperature and nutrient availability. The study in Ethiopian highlands demonstrated that plastic mulch contributed to a more favorable thermal environment, enhancing nutrient release from the soil. This has direct implications for the nutrient availability necessary for optimal crop growth. In Ethiopia, characterized by diverse agroecological zones with varying nutrient profiles, Tadesse T, et al. [28] explored how wheat straw mulch influenced nutrient availability for barley. The research revealed that mulching positively impacted nutrient dynamics, contributing to improved soil fertility. This understanding is vital for Ethiopian farmers seeking to optimize nutrient availability for specific crops.

Correlation with Crop Nutrient Uptake

The correlation between mulching practices and crop nutrient uptake is a key consideration in assessing the overall implications for crop growth. Globally, Ouellet E, et al. [42] investigated the correlation between plastic mulch and nutrient uptake in potatoes. The study demonstrated that the enhanced soil conditions created by mulching positively influenced nutrient uptake by crops. In African agriculture, where nutrient deficiencies are common, Assefa S, et al. [47] explored the correlation between plastic mulch, nutrient availability, and nutrient uptake in tomatoes. The study highlighted that the improved nutrient availability resulting from mulching practices positively correlated with increased nutrient uptake by tomato plants, contributing to enhanced growth. In Ethiopia, where optimizing nutrient uptake is essential for agricultural productivity Assefa S, et al. [47], Tadesse T, et al. [28] assessed the correlation between wheat straw mulch and nutrient uptake in barley. The research indicated that mulching positively influenced nutrient uptake patterns, emphasizing the role of mulching in supporting crop nutrition in Ethiopian farming systems.

Challenges and Limitations in the Implementation of Mulching

Mulching, a beneficial practice, faces challenges in its widespread implementation due to the availability and affordability of materials [50]. In developing countries, smallholder farmers face difficulties accessing suitable materials due to economic constraints and limited availability in local markets [51]. In Ethiopia, the implementation of plastic mulch faces challenges due to its cost and availability [47]. The diversity of agroecological zones in Ethiopia also introduces additional constraints [52]. In Ethiopia, the complex topography and diverse climates may introduce confounding factors [53]. Generalizing the findings of mulching studies to different regions and crops requires careful consideration of the context-specific nature of agricultural systems [28]. In Ethiopia, regional variations in climate, altitude, and farming practices necessitate caution when interpreting the results of studies on plastic mulch effects [54].

Contributions to Existing Knowledge

The research on mulching effects contributes significantly to the existing body of knowledge in agriculture and soil science. Globally, studies such as those by Ouellet E, et al. [42] have expanded our understanding of how different mulching materials, including plastic, influence soil temperature and microbial biomass. These contributions are essential for guiding farmers and policymakers toward informed decisions regarding mulching practices. In Africa, particularly in Ethiopia, the studies by Belay SA, et al. [55] add valuable context-specific insights, showcasing the adaptability of mulching practices to diverse agroecological zones. The emphasis on the role of mulching in enhancing soil fertility, moisture retention, and overall crop productivity enriches the existing knowledge base and underscores the importance of tailored solutions for sustainable agriculture [15].

Future Research Directions

Research on mulching's impact on soil temperature regulation and crop growth is expanding globally, with potential implications for Africa, Ethiopia, and other regions. Future studies should explore long-term effects on soil health, carbon sequestration, ecosystem resilience, and interactions between mulch types and crops. In Africa, socio-economic implications and scalability of mulching practices could be explored. In Ethiopia, regional variations and climate change mitigation potential should be assessed. This research domain offers insights for sustainable agricultural strategies.

Conclusion and Recommendations

Mulching practices have been consistently used in sustainable soil management across diverse global, African, and Ethiopian contexts, highlighting their inherent value in enhancing soil fertility, conserving water, and promoting sustainable agriculture. Mulching plays a crucial role in regulating soil temperature, with global patterns observed while considering the specificities of African agriculture and the diverse landscapes of Ethiopia. Spatial variations in soil temperature within agricultural plots are influenced by mulching, creating optimal thermal environments for crop growth. Mulching materials have been found to reduce spatial variability in soil temperature, ensuring uniform crop development and yield. Mulching positively impacts nutrient dynamics and availability, contributing to improved soil fertility and optimizing nutrient availability for specific

crops. Overall, understanding the effects of mulching on soil temperature regulation and its implications for crop growth is crucial for sustainable and resilient farming practices. Implementing tailored recommendations that address the specific needs of each region can enhance agricultural productivity, soil health, and the resilience of farming systems.

- Implement mulching practices in Ethiopian agriculture to regulate soil temperature and create a more stable thermal environment for crops, leading to improved plant physiological processes and enhanced crop productivity.
- Emphasize the importance of mulching in optimizing land use and ensuring consistent crop performance, particularly in diverse topographies.
- Encourage the adoption of sustainable mulching practices that promote soil fertility, conserve water, and contribute to the resilience of farming systems.
- Conduct further research and case studies to understand crop-specific responses to mulching practices in different regions of Ethiopia.

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