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Role of Mulching in Drought Management

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Drought is one of the most devastating abiotic stresses threatening global agricultural productivity, food security, and ecosystem stability. As climate change intensifies the frequency and severity of drought events worldwide, there is an urgent need for sustainable, low-cost, and eco-friendly management strategies. Mulching — the practice of covering the soil surface with organic or inorganic materials — has emerged as a highly effective agronomic technique for mitigating drought-induced stress. This review examines the multifaceted role of mulching in drought management, encompassing its effects on soil moisture conservation, temperature regulation, weed suppression, and improvement of soil physical and biological properties. The article also explores different types of mulches — including straw, plastic, wood chips, and living mulches — and evaluates their comparative effectiveness under varied agro-climatic conditions. Evidence from field studies and experimental trials consistently demonstrates that mulching can reduce soil water evaporation by 20–50%, enhance crop water-use efficiency, and significantly improve plant growth parameters under drought stress. The authors' perspectives highlight practical implications for smallholder farmers and policy recommendations for large-scale adoption. This review affirms that mulching represents a cornerstone practice in sustainable drought management and climate-resilient agriculture.

Keywords: Mulching, Drought Management, Soil Moisture Conservation, Water-Use Efficiency, Organic Mulch, ClimateResilient Agriculture, Evapotranspiration, Soil Temperature.

Introduction

Drought, broadly defined as a prolonged period of abnormally low precipitation relative to the long-term average, represents one of the most complex and far-reaching natural disasters affecting agricultural systems globally. The Food and Agriculture Organization (FAO) estimates that drought accounts for approximately 35% of all crop production losses worldwide, disproportionately affecting smallholder farmers in arid and semi-arid tropical regions. In the context of accelerating climate change, rising temperatures and shifting precipitation patterns are projected to exacerbate drought conditions across large portions of South Asia, Sub-Saharan Africa, the Mediterranean basin, and parts of the Americas. The management of drought in agricultural landscapes requires a multidisciplinary approach integrating hydrological, agronomic, and ecological strategies. Among these, soil surface management practices occupy a central role. The soil– plant–atmosphere continuum governs the movement of water from the soil through roots and leaf surfaces into the atmosphere. Any intervention that reduces water loss from the soil surface or improves the soil's water-holding capacity directly contributes to drought resilience. Mulching is among the oldest and most widely applied soil management techniques known to agriculture. Archaeological and historical records suggest that farmers in ancient civilizations used organic residues to cover crop fields, intuitively recognizing the benefits of retained soil moisture and reduced weed competition. Modern agricultural science has validated these empirical observations with quantitative rigour, demonstrating the profound influence of mulching on the soil microenvironment, plant physiology, and ultimately crop yield under water-deficit conditions. The term 'mulch' encompasses a broad spectrum of materials — ranging from agricultural by-products such as straw, rice husk, and sugarcane bagasse to synthetic materials such as polyethylene film and biodegradable plastics. Each mulch type interacts differently with the soil, the crop canopy, and the local climate, necessitating context-specific recommendations. This review synthesizes current scientific knowledge on the role of mulching in drought management, analyzes comparative evidence across mulch types and cropping systems, and offers perspectives on the future directions for research and policy.

Mechanisms of Mulching in Soil Moisture Conservation

The primary mechanism through which mulching contributes to drought management is the reduction of evaporative water loss from the soil surface. Evaporation from bare soil, particularly during hightemperature daytime periods, constitutes a significant component of total water loss in agroecosystems. Research consistently indicates that an effective mulch layer can suppress direct soil evaporation by 20– 50%, depending on the mulch material, thickness, and crop stage. This is achieved through the physical barrier effect of the mulch, which reduces the aerodynamic exchange of water vapour between the moist soil surface and the overlying air mass. Additionally, mulching reduces the soil surface albedo and modifies the energy balance at the soil– atmosphere interface. Organic mulches generally have higher reflectance than bare dark soils, thereby reducing incoming solar energy absorption and, consequently, the energy available for evaporation. Plastic mulches, depending on their colour (black, silver, or clear), can either suppress or enhance soil temperature, affecting both evaporation and crop root-zone hydrology. Mulch layers also improve soil infiltration by preventing surface sealing and crusting, which are common consequences of raindrop impact on bare soils. By maintaining an open, porous soil surface structure, mulches facilitate the rapid percolation of rainfall or irrigation water into the root zone, reducing runoff and increasing effective precipitation. Studies on sloped agricultural lands in semi-arid regions of India and Ethiopia have demonstrated runoff reductions of 30–70% under mulched conditions compared to bare plots.

Types of Mulches and Their Comparative Effectiveness

Organic mulches, derived from plant materials, are the most widely used category globally. Straw mulch, applied at rates of 4–8 tonnes per hectare, has been shown to reduce soil temperature by 3–8°C during peak summer months and increase volumetric soil moisture content by 15–30% compared to unmulched controls in wheat and maize production systems. Straw mulch also decomposes progressively, contributing organic matter, improving soil structure, and enhancing microbial activity, all of which support long-term soil health. Plastic mulches, particularly black polyethylene film, are extensively used in high-value vegetable production and fruit crop cultivation. Black plastic mulches effectively suppress weed growth by blocking photosynthetically active radiation, reduce soil evaporation, and maintain more stable soil temperatures. However, their ecological footprint, including microplastic contamination and disposal challenges, has prompted growing interest in biodegradable alternatives made from polylactic acid (PLA) or starch-based composites. Living mulches, consisting of low-growing cover crops sown in the interrows of main crops, represent an ecologically integrated approach. Species such as clover (Trifolium spp.), ryegrass (Lolium perenne), and cowpea (Vigna unguiculata) have been evaluated as living mulches in diverse cropping systems. While they compete with the main crop for water under extreme drought conditions, their benefits in terms of nitrogen fixation, soil cover, and biodiversity support are well documented. Careful species selection and management timing are critical to maximizing their net benefits under waterlimited conditions.

Effect of Mulching on Soil Temperature and Microbial Activity

Soil temperature regulation is a critical but sometimes underappreciated dimension of mulching's drought management role. Extreme soil surface temperatures under bare conditions can exceed 50–60°C in tropical regions, causing severe damage to surface-feeding roots, desiccation of soil microorganisms, and accelerated organic matter decomposition. Mulch layers buffer these extremes, maintaining soil temperatures within the optimal range for root activity (20–35°C), which supports continued nutrient uptake even under moisture stress. Stable soil temperatures under mulch promote enhanced microbial biomass and diversity. Soil bacteria, fungi, and actinomycetes play critical roles in nutrient cycling, particularly the mineralization of nitrogen and phosphorus. Studies using 16S rRNA amplicon sequencing have demonstrated significantly higher microbial diversity indices in mulched soils compared to bare soils under drought conditions, with implications for sustained crop nutrition and disease suppression during water-deficit periods.

Mulching and Crop Physiological Responses

At the plant physiological level, the conservation of soil moisture under mulch translates into maintained leaf water potential, sustained stomatal conductance, and higher rates of photosynthesis during periods of limited precipitation. Research on drought-stressed tomato (Solanum lycopersicum) crops under straw mulch reported a 25% higher leaf relative water content and a 40% increase in net photosynthetic rate compared to unmulched controls, directly attributable to improved soil water availability. Mulching also influences root architecture under drought conditions. Plants growing in mulched soils have been observed to develop shallower but more extensively branched root systems, maximising exploitation of the moist upper soil layers preserved by the mulch. This contrasts with the deep, sparse root systems typical of drought-stressed plants in bare soils, which expend significant carbohydrate resources in root elongation with diminishing returns in water acquisition.

Mulching in Integrated Drought Management Systems

Mulching does not function in isolation but is most effective when integrated within a broader suite of drought management practices. Combined with deficit irrigation techniques such as drip irrigation or sub-surface irrigation, mulching significantly amplifies water-use efficiency gains. Studies from dripirrigated pepper and cucumber production in arid regions of Morocco and Pakistan demonstrated water savings of 35–55% when drip irrigation was combined with plastic mulching compared to flood irrigation alone. Incorporation of mulching into conservation agriculture systems, which also include minimum tillage and diverse crop rotations, addresses drought vulnerability at the systems level. Minimum tillage preserves soil macropore continuity, facilitating deep water infiltration, while mulch residues maintain surface cover. Long-term trials under conservation agriculture frameworks in sub-Saharan Africa have reported yield stability improvements of 20–40% in drought-prone years relative to conventional tillage systems.

Authors' Perspectives

From the perspective of the authors, the evidence unequivocally supports the centrality of mulching as a drought management tool, yet its adoption at the farm level remains inconsistent and far below its potential, particularly in smallholder farming contexts in South and Southeast Asia. A key barrier is the availability of adequate mulch material, especially in regions where crop residues are routinely burned or used as fodder. Policy frameworks that incentivize residue retention and provide subsidized access to mulch materials could unlock significant drought resilience dividends. The authors also highlight the need for location-specific research to establish optimal mulch types, application rates, and timing for diverse agro-climatic zones. A 'one-size-fits-all' recommendation is inappropriate given the variability in soil types, crop species, rainfall patterns, and local resource availability. Participatory research approaches, co-designed with farming communities, are essential to develop context-relevant mulching guidelines that are technically sound and practically adoptable.

Conclusion

Mulching stands as one of the most powerful, affordable, and ecologically sound strategies available for managing drought in agricultural systems. Its multifunctional impacts — conserving soil moisture, moderating temperature extremes, suppressing weeds, improving soil health, and enhancing crop physiological performance — collectively contribute to greater resilience in the face of water deficit stress. The growing body of scientific evidence affirms that mulching is not merely a supplementary practice but a foundational element of climate-smart, drought-resilient agriculture. In conclusion, the role of mulching in drought management transcends agronomy and connects to broader imperatives of food security, environmental sustainability, and rural livelihoods. As the world confronts an era of intensifying climatic uncertainty, mulching offers a timely, proven, and scalable solution that deserves far greater attention and investment from the global agricultural community.

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