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Sustainable Management of Semi-Arid Horticultural Systems: Sheep Wool Mulching as a Circular Economy Solution for Water Conservation

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Abstract

In semi-arid regions such as Albacete, Spain, horticultural production is increasingly threatened by extreme climatic shifts, characterized by high summer evapotranspiration rates and significant winter frost risks. This research evaluates the technical viability of raw sheep wool, a currently undervalued and problematic livestock byproduct, as a sustainable, biodegradable mulching material designed to optimize water use efficiency and soil health (Broda et al., 2023). The study employed dual methodology, integrating laboratory analysis and field trials. The performance of wool mulching was compared against five treatments: bare soil (control), cereal straw, a wool-straw blend (50% v/v), geotextile mesh, and a commercial biodegradable film. Laboratory results demonstrated that raw wool was the most effective material for water conservation, achieving a soil water retention rate of 68.59% and reducing evaporation to 31%, whereas bare soil lost nearly 79% of its moisture content. This performance is attributed to the porous and fibrous structure of the keratin fibers, which showed a high-water absorption capacity (8.38%), facilitating a gradual and controlled moisture release into the rhizosphere. This aligns with findings regarding the physical properties of wool in agricultural applications, which emphasize its low thermal conductivity and high hygroscopicity (Broda, 2019). Field trials conducted on various leafy vegetables corroborated these findings. Organic mulches, particularly the wool and wool-blend treatments, functioned as superior thermal regulators. These materials stabilized soil temperatures within a range of 24°C to 28°C, while bare soil reached stress-inducing peaks exceeding 32°C, which can inhibit root development and nutrient uptake. Physiological monitoring through SPAD units indicated that mulching improved chlorophyll concentration across all botanical families studied, with the wool-straw combination being particularly effective for leafy species. As noted in recent literature, the integration of wool waste into soil management not only improves crop physiology but also enhances soil organic matter over time (Lal et al., 2020). In conclusion, raw sheep wool represents a high-performance, multi-functional alternative for soil management in water-scarce environments. By converting a livestock waste product into a valuable agronomic resource, this practice supports circular economy models and directly aligns Sustainable Development Goals (SDGs) 6, 12, and 13, promoting climate resilience and sustainable resource consumption in modern agriculture.

Keywords: Mulching, Sheep Wool, Water Retention, Circular Economy, Soil Temperature