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Review Article

Deficit Irrigation and Mulching Impacts on Major Crop Yield and Water Efficiency: A Review

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Abstract: The review examines the impact of deficit irrigation and mulching materials on crop yield and water use efficiency. The challenges posed by population growth and climate change necessitate new solutions to improve agriculture. The best irrigation strategies yield large yields for a given amount of water. Deficit irrigation and mulching significantly increase water use efficiency and crop yield for various crops. However, water supply constraints have led to the development of deficit irrigation; a strategy that maximizes water use efficiency without yield penalty. Mulch is a vital method for conserving soil moisture, preventing weed growth, reducing evaporation, and increasing infiltration of rainwater during the growing season. Different mulching methods and materials are used worldwide, with plastic and straw being the most popular and optimistic results. Straw mulch conserves higher soil moisture by 55% more compared to the control, and crops under straw mulch produce higher branches, fruit weight, and total yield. Polyethylene mulches have induced large increases in growth and yields for various vegetables, including tomato. However, the economic profitability of this mulch is low, so straw mulch is better for economic profitability. Plastic cover ridge furrow methods are better for increasing water use efficiency (WUE) and crop yield, reducing soil evaporation and erosion, increasing top soil temperature, creating a microenvironment for soil microbial activity, and increasing sustainability.

Keywords: Deficit Irrigation, Mulching, Water Use Efficiency

1. Introduction

Water shortages caused by population expansion and irregular precipitation increase agriculture's demand, necessitating new solutions for sustainable agriculture. Cooperative irrigation management aims to maximize water use efficiency and maintain soil moisture for plants [1]. Producers adopt time deficit irrigation to achieve high yields without reaching field capacity Mulching and deficit irrigation are strategies to decrease water use in agriculture, benefiting crop production and yield, especially under low water availability. This reduces the frequency of phytosanitary measures and production costs [1, 2].

1.1. Irrigation Deficit

Conventional irrigation development focuses on avoiding water deficits to achieve maximum yields [3]. However, water supply constraints have led to the development of DI, a strategy that maximizes water use efficiency without yield penalty [4, 5]. DI requires detailed irrigation management and identifies crop characteristics and stress-related yield come backs [6]. DI involves applying water below optimal evapotranspiration levels, reducing water use while minimizing adverse impacts on yield [7]. It aims to stabilize yields and achieve maximum crop water productivity, improving water productivity and reducing irrigation application [50].

1.2. Water Use Efficiency

Water use efficiency (WUE) is a concept that compares crop production to water usage. The best irrigation strategies produce a large yield for a given amount of irrigation [8]. Producers often aim to increase profits, but determining the level of irrigation needed can be complex and depends on biophysical and economic factors [9]. WUE is the main criterion for evaluating production systems in areas with limited water resources, where water is the greatest limitation to production [10, 11].

1.3. Mulching

Mulching is an in-situ moisture preservation system that maintains soil moisture, reduces weed growth, and mitigates erosion. It improves crop yield and water use efficiency [12]. The degree of drop between mulch and soil affects soil warming [13].

1.4. Soil Moisture Management

Soil and water-management systems aim to encourage water infiltration, but often fail to optimize water flow along crop rooting zones, leading to poor yields due to soil moisture insufficiency rather than rainfall insufficiency [31]. Proper moisture conservation is crucial, as moisture deficits can severely depress crop yields, while adequate management can increase yields by a factor two or more [6].

1.5. Water Saved

Mulching is a water-saving technique in dryland areas that conserves soil moisture, regulates temperature, and reduces evaporation [14-16]. Its main strength is reducing surface evaporation and controlling soil erosion). Mulching decreases irrigation demand during crop cultivation periods by reducing soil evaporation and regulating temperature [16-18]. The amount of water saved by mulching is critical due to the interaction of microclimate, soil environment, and plant growths [19].

1.6. Retains Moisture

Organic and non-organic mulches cover soil, limit evaporation, absorb water, and retain moisture for plant growth. They help reduce water bills during hot and humid summers, providing water for plants and reducing physical water requirements for gardens.

2. Results and Discussion

Effect of Deficit Irrigation and Mulches on Water Use Efficiency and Crop Yield

Mulch is a crucial method for conserving soil moisture, as it helps prevent weed growth, reduce evaporation, and increase infiltration of rainwater during the growing season. Plastic mulch helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water, and may help reduce the incidence of moisture-related physiological disorders such as blossom end rot on vegetables and fruit cracking in lime and pomegranate [20]. Mulch provides numerous benefits to crop production through soil and water conservation, enhanced soil biological activity, and improved chemical and physical properties of the soil. Studies have shown that mulches conserve more soil moisture, enhance vegetative growth and yield-committing characteristics of garlic [21-23]. Crop residues or mulch at the soil surface act as shade and serve as a vapour barrier against moisture losses from the soil, causing slow surface runoff. Straw mulch conserves higher soil moisture to an extent of 55% more compared to the control. Crop under straw mulch produced higher number of branches, fruit weight, and total yield compared to no mulch [24]. Polyethylene mulches have induced large increases in growth and yields for various vegetables, including tomato [26-29]. These increases have been attributed to changes in soil and air temperature near the cover, soil water balance, and nutrient availability compared to un mulched soil [30-33]. Less soil compaction and improved aeration under mulched soil have also contributed to increased plant growth [34]. In situations where water productivity is increased, priority for polyethylene mulch may be the option. However, the economic profitability of this mulch is low, so it is better to use straw mulch for economic profitability [35].

Table 1. *Influence of water regimes on tuber yield of potato for mulched (M) and non-mulched (NM) plots.*

Water level	Tuber yield t/ha				
	100%	90%	80%	60%	50%
Mulch	31.5	29.6	28.9	26.9	23.2
Non Mulch	28.3	25.8	24.9	21.9	20.3

Source [36].

The study found that half mulched maize straw yielded the highest grain yield and water use efficiency. However, this pattern was more favorable for wheat growth, soil temperature, and water efficiency. Plastic cover ridge furrow methods are better for increasing water use efficiency (WUE) and crop yield. They also reduce soil evaporation and erosion in arid and semiarid conditions, increase top soil temperature, create a microenvironment for soil microbial activity, and increase sustainability [37].

Mulch enhances soil physical properties through aggregation, increased water content, and reduced runoff, leading to better germination and higher yield. It also increases nutrient availability to plant roots, leading to higher grain yield. Plastic mulch increases grain yield by 17% and above ground biomass by 19% [38]. The bed planting method of full irrigation with plastic mulching soil condition yields higher baby corn yield. The system also increases soil temperature, accelerates early growth, plant height, fruiting, and provides satisfactory weed control without herbicide application. In the top soil layer, mulching treatment significantly increases soil water content, with high nitrate-N content distributed. The yield increased with increased basal fertilizer, top dressing, and plastic film mulching, improving fertilizer use efficiency [39]. Plastic film mulching can be effectively utilized for improving productivity and water use efficiency in rice production [40]. Straw mulching reduces soil evaporation by 43mm for maize and WUE by over 10%, indicating that water use efficiency increases with the decrease in irrigation depth applied.

Plastic mulch has been shown to increase crop yield by improving solar energy, water, and fertility status, reducing soil water loss, and removing weeds [41-43]. This can lead to increased grain yield and water use efficiency (WUE). Mulching with plastic film has been shown to enhance water use efficiency by 14%, grain yield by 17%, and biological yield by 19%. The soil on top of mulch retains structural stability and lower bulk density compared to un-mulched soil, likely due to less structural disruption of aggregates and settlement in unsaturated conditions [49]. Plastic sheet mulch is more effective for conservation of soil water than that of wheat straw mulch [44]. Experiment conducted in Nigeria to study the effects of deficit irrigation and mulch on onion yield, water use, and crop water productivity [45]. Results showed that irrigating onion at 25% of weekly reference evapotranspiration reduced bulb yield by 50%. Applying water at 50% and 75% water requirements led to a 15.5-23% reduction in yield and higher water use efficiency. Yield reductions reported in 78%, 45%, and 15% when onion crop was irrigated at 25%, 50%, and 75% of ET c [46]. Study found that onion bulb yield decreased with increasing water deficit levels, while both water use and irrigation water use efficiencies increased with water deficit levels [47, 48]. Deficit irrigation and mulch had significant positive impacts on growth parameters like plant height, scape length and diameter, and umbel diameter.

3. Conclusion

Mulch is a vital method for conserving soil moisture, preventing weed growth, reducing evaporation, and increasing infiltration of rainwater during the growing season. It also helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. Mulch provides numerous benefits to crop production through soil and water conservation, enhanced soil biological activity, and improved chemical and physical properties of the soil. Studies have shown that mulches conserve more soil moisture, enhance vegetative growth, and yield-committing characteristics. Straw mulch conserves higher soil moisture by 55% more compared to the control, and crops under straw mulch produce higher branches, fruit weight, and total yield. Polyethylene mulches have induced large increases in growth and yields for various vegetables, including tomato. However, the economic profitability of this mulch is low, so straw mulch is better for economic profitability. Plastic cover ridge furrow methods are better for increasing water use efficiency (WUE) and crop yield, reducing soil evaporation and erosion, increasing top soil temperature, creating a microenvironment for soil microbial activity, and increasing sustainability.

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