



Plastic Mulch and Drip Irrigation for Improving Water Productivity in Horticultural Crops under Semi-Arid Conditions

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ABSTRACT

Water scarcity and high evaporative demand constrain horticultural production in semi-arid environments. Plastic mulching and drip irrigation are complementary water-management practices that can improve soil-moisture conservation, irrigation efficiency and crop productivity. Drip irrigation delivers water near the crop root zone, while plastic mulch limits direct evaporation from the soil surface and modifies the soil thermal environment. Published studies in strawberry, tomato, brinjal and other horticultural crops have reported improvements in yield and water-use efficiency under integrated mulch and drip irrigation systems. However, the magnitude of these benefits depends on crop species, mulch properties, irrigation scheduling, soil characteristics and local climatic conditions. This communication examines the potential of integrating plastic mulching with drip irrigation for water-efficient horticultural production under semi-arid conditions. It also highlights the importance of quantifying irrigation water applied, marketable yield, irrigation water productivity and economic returns when evaluating these practices. Although technology offers considerable potential for improving water productivity, appropriate plastic waste collection, recycling and assessment of long-term soil impacts are necessary for sustainable adoption. Site-specific evaluation is therefore essential before recommending the technology across diverse horticultural production systems.

KEYWORDS: Drip irrigation; plastic mulch; water productivity; horticultural crops; semi-arid climate; sustainable plasticulture

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1. INTRODUCTION

Water availability is a major constraint to sustainable horticultural production in semi-arid regions, where high atmospheric evaporative demand and irregular rainfall can increase irrigation requirements. Efficient water management is particularly important for horticultural crops because both yield and marketable quality can be affected by fluctuations in soil moisture during critical growth and fruit-development stages. Improving the productivity of irrigation water is therefore an important strategy for sustaining horticultural production under limited water availability.

Drip irrigation and plastic mulching are widely used technologies for improving crop water management. Drip irrigation supplies water directly to the root zone, potentially reducing losses associated with surface evaporation, runoff and deep percolation when the system is properly designed and managed. Plastic mulch covers the soil surface, suppresses evaporation, modifies soil temperature and can reduce weed emergence. The combined application of these practices may provide complementary benefits by maintaining a more favourable soil-water

environment while improving the efficiency of irrigation.

Research on horticultural crops supports the potential of integrated mulch and drip irrigation systems. Kumar and Kumar (2020) reviewed the effects of drip irrigation combined with mulching and reported improvements in soil-moisture conservation and crop performance across the studies considered. Similarly, Shivani et al. (2019) evaluated drip irrigation and polyethylene mulch in tomato and brinjal under eastern Indian conditions and reported higher yields and water productivity under the combined treatment than under conventional furrow irrigation. Evidence from strawberry cultivation also indicates that irrigation method and mulch material can influence yield, root growth and water-use efficiency (Létourneau et al. 2011).

Despite these encouraging findings, the response to plastic mulching and drip irrigation is not uniform across crops and environments. Mulch colour, film properties, soil texture, irrigation scheduling, crop architecture and local weather conditions can alter the magnitude and direction of the response. Consequently, locally relevant evaluation is required to determine

the agronomic and economic suitability of the technology under semi-arid conditions.

2. COMPLEMENTARY ROLES OF PLASTIC MULCH AND DRIP IRRIGATION

2.1. Drip irrigation for efficient water delivery

Drip irrigation supplies water in controlled quantities near plant roots, allowing irrigation to be scheduled according to crop demand and soil-water status. Compared with conventional surface irrigation, a properly designed drip system can reduce non-beneficial water losses and improve the uniformity of water application. Its effectiveness depends on emitter discharge, operating pressure, filtration, irrigation frequency, soil infiltration characteristics and maintenance of the system.

For horticultural crops, irrigation scheduling should account for crop growth stage, rooting depth, soil moisture and prevailing weather conditions. Excessive irrigation may reduce the expected water-saving benefits, while severe water deficits can adversely affect crop growth, yield and fruit size. Thus, the objective should be to improve crop water productivity without compromising marketable yield or quality.

2.2. Plastic mulching for soil-moisture conservation

Plastic mulch acts as a physical barrier between the soil surface and the atmosphere, reducing direct evaporation from the covered soil. Its effect on soil temperature depends on film colour, optical properties, soil contact and climatic conditions. Black polyethylene, for example, absorbs solar radiation and can increase root-zone temperature under some conditions. This response may be beneficial during cool periods but undesirable when soil temperatures are already high.

Mulching may also suppress weeds and reduce direct contact between fruits and soil. However, the benefits depend on crop type, mulch installation, irrigation placement and management practices. The selection of mulch should therefore consider both the agronomic objective and the thermal environment in which the crop is grown.

2.3. Integrated application of mulch and drip irrigation

Combining plastic mulch with drip irrigation can improve the management of water within the crop root zone. Drip lines supply water beneath or close to the covered soil surface, while the mulch restricts direct evaporation. This integration can help maintain soil moisture between irrigation events and may support improved crop growth and yield.

In a semi-arid setting, the combined system is potentially useful because water conservation and precise irrigation are both important. Nevertheless, the benefits should be quantified using measured irrigation volumes and crop yield rather than inferred solely from the presence of mulch and drip lines.

3. EVIDENCE FROM HORTICULTURAL CROPS

Shivani et al. (2019) studied tomato and brinjal over three growing seasons in the eastern plains of India. The authors reported that drip irrigation combined with black polyethylene mulch improved yield and water productivity compared with conventional furrow irrigation. Their findings illustrate the potential of integrated water and soil-surface management in vegetable production, although the reported values should not be assumed to apply directly to other regions or crops.

In strawberry, Létourneau et al. (2011) examined different

mulches and irrigation methods under sub-temperate conditions in Himachal Pradesh. The study showed that irrigation method and mulch material influenced soil moisture, root growth, nutrient uptake, water-use efficiency and yield. A separate study by Sharma et al. (2005) also documented differences in strawberry yield, fruit characteristics and water-use efficiency across drip irrigation and mulch treatments under mid-hill conditions.

More recently, a study by Biswas et al. (2025) evaluated irrigation and mulch regimes in strawberry and demonstrated that water-use efficiency and crop performance varied with the combinations of irrigation and mulch treatments. Such findings emphasize the need to consider the specific production environment and the type of mulch used when developing recommendations.

Collectively, these studies support the use of plastic mulching and drip irrigation as a potential strategy for improving water productivity. However, differences in experimental design, crop species, irrigation levels and methods of calculating water-use efficiency limit direct comparison among studies. The results should therefore be interpreted in the context of their respective agroecological conditions.

4. IMPLICATIONS FOR SEMI-ARID HORTICULTURAL PRODUCTION

For semi-arid horticultural regions, integrated plastic mulching and drip irrigation may offer benefits in water management, crop establishment and production efficiency. However, recommendations should be based on local measurements of irrigation water applied, marketable yield, fruit quality and production costs.

A suitable field evaluation should compare the combined treatment with the prevailing conventional practice under comparable crop-management conditions. Irrigation water should be measured separately for each treatment, and yield should be recorded on a plot basis and expressed per unit area. Water productivity can then be calculated as marketable yield divided by the volume of irrigation water applied.

Where rainfall contributes appreciably to crop water supply, the distinction between irrigation water productivity and total water productivity should be maintained. Economic assessment should include the cost of drip installation, mulch purchase, installation labour, system maintenance, removal and disposal of used plastic. These costs are important when assessing whether increased yield or improved water productivity translates into a net economic benefit.

Environmental management is equally important. Conventional plastic films can generate agricultural plastic waste if they are not recovered after use. Damaged films and residual plastic may accumulate in soil or require costly removal. Collection, recycling and appropriate disposal should therefore be included in the recommended package of practices. Biodegradable mulch materials may be considered where their performance, degradation characteristics and economic suitability have been established.

5. RESEARCH PRIORITIES

Further work should focus on quantifying the performance of integrated plastic mulch and drip irrigation under specific semi-arid production conditions. Priority areas include:

1. Comparing irrigation water applied, marketable yield and irrigation water productivity under combined and conventional practices.
2. Evaluating the influence of mulch colour, film thickness and irrigation scheduling on soil moisture and crop response.
3. Determining the economic feasibility of the technology under local input costs and market prices.
4. Assessing the management of used plastic mulch and the suitability of alternative mulch materials.
5. Conducting multi-season and multi-location evaluations to establish the consistency of crop responses.

Such evaluations would provide a stronger evidence base for developing region-specific recommendations for water-efficient horticultural production.

6. CONCLUSION

Plastic mulching combined with drip irrigation offers a promising approach to improving soil-moisture conservation and irrigation water productivity in horticultural crops under semi-arid conditions. Published studies in vegetables and strawberry indicate that the response can be favourable, but the magnitude of improvement depends on crop, mulch characteristics, irrigation management and local environmental conditions. Adoption recommendations should therefore be supported by site-specific measurements of irrigation water, marketable yield, crop quality and economic returns. Effective recovery and management of used plastic mulch are also essential to ensure that the productivity benefits of plasticulture are consistent with long-term environmental sustainability.

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Author Contributions

All authors conceived the concept, wrote and approved the manuscript.

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