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Can Precision Irrigation be an Effective Approach to Suppress Weed Pressure in Organic Lettuce Systems?

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Introduction

Weed management remains one of the most persistent and costly challenges in organic farming, particularly in organic iceberg lettuce production systems. Organic growers, restricted from using synthetic herbicides, must rely on a combination of cultural, mechanical, and biological practices to suppress weeds while maintaining soil health and crop productivity. Among these strategies, the principle of "**Feed and Water the Crops, Not the Weeds**" underscores the importance of managing water and nutrients in a way that favors crop growth and limits weed emergence (Schonbeck, 2012, accessed July 31, 2025).

Precision irrigation, especially through micro-irrigation systems, such as surface or subsurface drip lines, has emerged as a promising tool for reducing weed pressure in organic production systems. Delivering water directly to the crop root zone, these systems minimize wetting of the soil surface, thereby creating unfavorable conditions for many common weed seeds, which typically require light and moisture to germinate (Shrestha, Lanini, & Wright, 2007). Unlike other irrigation methods that uniformly wet the entire field, precision irrigation allows growers to target crop needs more accurately while minimizing water to weed-prone zones.

Recent studies have demonstrated that subsurface drip irrigation (SDI) can significantly reduce weed biomass compared to furrow or sprinkler irrigation in vegetable cropping systems. For example, research conducted in California's Central Valley found that SDI systems reduced weed biomass by over 50% while maintaining or improving lettuce yields (Smith et al., 2011). When combined with sensor-based irrigation scheduling, which uses real-time soil moisture data to inform precise and timely irrigation decisions, growers can enhance water-use efficiency, reduce evaporation losses, and disrupt the weed life cycle, improving weed suppression sustainably (Sticlaru, 2024, accessed July 31, 2025).

Given the growing pressures on water resources and the high labor demands of mechanical weed control, adopting precision irrigation strategies represents a vital step toward improving both water-use efficiency and weed suppression in organic lettuce production. Integrating these technologies into organic systems offers a dual benefit: enhancing crop productivity while reducing one of the most labor- and resource-intensive management challenges faced by organic growers.

How Does Precision Irrigation Suppress Weed Growth in Organic Lettuce Production?

Precision irrigation systems, especially SDI, suppress weed growth by altering the soil moisture profile in ways that are unfavorable for weed seed germination. Most weed species require light, warmth, and moisture near the soil surface to germinate and establish. By contrast, SDI delivers irrigation water directly to the root zone of the crop, typically 4 inches or less below the surface for lettuce in the southwest desert environmental conditions, leaving the topsoil relatively dry. Unlike overhead or furrow irrigation systems, which wet the entire soil surface and unintentionally encourage weed emergence between crop rows, SDI targets only the crop root zone. This approach provides the lettuce crop a competitive advantage while depriving weeds of moisture in the inter-row spaces. Over time, this selective watering can lead to lower weed pressure, reduced cultivation passes, and lower labor costs for hand-weeding.

In addition to surface drying, precision irrigation reduces soil splashing and maintains more consistent temperatures in the root zone, which can suppress the emergence of some soilborne weed seeds and reduce pathogen spread. This can be especially beneficial in organic systems, where synthetic fungicides and herbicides are not used.

Furthermore, integrating sensor-based scheduling with these irrigation systems enhances their efficiency. When irrigation is applied only when and where needed, based on real-time soil moisture and crop evapotranspiration data, it minimizes overwatering and underwatering, which is a common driver of weed outbreaks. In summary, precision irrigation not only improves water-use efficiency but **also functions as a cultural weed control strategy in organic lettuce systems.**

In Yuma, Arizona, weed management in lettuce production is closely tied to seasonal temperatures and planting windows. During warmer early-season planting (late summer to early fall), surface irrigation methods like furrow or flood irrigation often create moist conditions ideal for warm-season weeds. As temperatures transition into cooler mid-season plantings (mid-fall), weed pressures shift, becoming more challenging to manage. By late fall and winter, cooler-season weeds emerge, requiring growers to carefully consider irrigation practices, such as subsurface drip irrigation, minimizing surface moisture, and effectively suppressing weed populations across these planting windows.

Ongoing Research: Evaluating Precision Irrigation for Weed Suppression in Organic Lettuce

This approach is currently being evaluated through a long-term research effort at the University of Arizona, Yuma Agricultural Center–Valley Research Center. One of the primary objectives of this study is to evaluate whether precise irrigation management practices employing subsurface drip irrigation and sensor-based scheduling can sustainably reduce weed populations by minimizing both overwatering and underwatering, thereby improving organic iceberg lettuce production.

To investigate this, the research team is utilizing advanced wireless soil sensor technology that can monitor soil moisture, salinity, and temperature at multiple depths across the soil profile. Real-time, data-driven measurements are being used to schedule irrigation and evaluate how soil moisture dynamics influence weed emergence across different production treatments (Figure 1).

Preliminary findings after one year are favorable, and the study is continuing. Weed pressure was consistently lower throughout the growing season in fields using subsurface drip irrigation (SDI), compared to nearby lettuce fields on the same farm that did not use precise irrigation methods (personal communication). Eliminating the need for organic herbicide treatments (Figure 2). Notably, this reduction in weed growth did not impact crop yield, suggesting that precision irrigation, when managed properly, can serve as a dual-purpose tool: conserving water, which may help suppress weed growth, although further research is needed to confirm this effect. This study is designed as a multi-year research project, and future research will provide deeper, quantitative insights into how precision irrigation impacts long-term weed dynamics and crop productivity in organic lettuce systems.

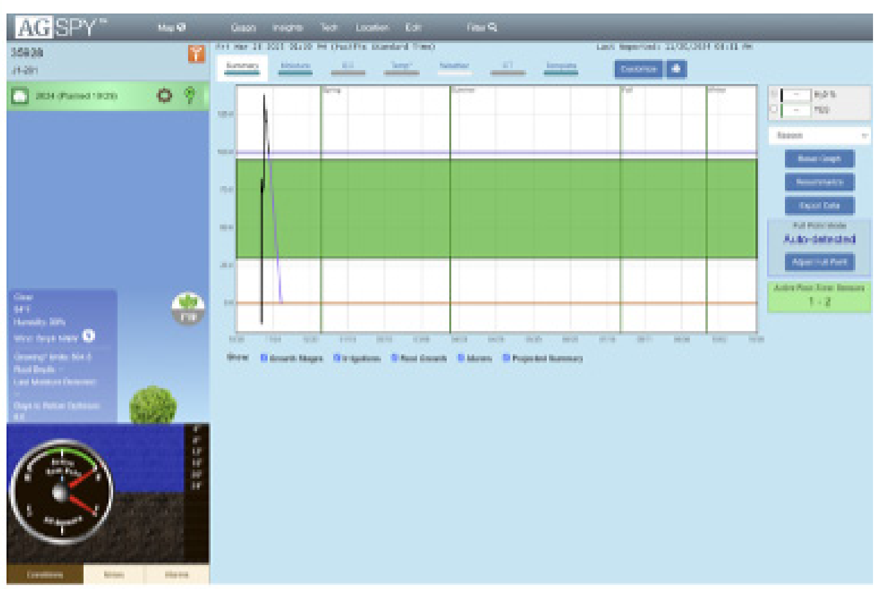

Figure 1. Wireless soil sensor from AquaSpy installed at the Valley Research Center, Yuma Agricultural Center, University of Arizona (left), used to measure soil moisture levels, salinity, and temperature at multiple depths. Photo credit: Ali Mohammed. The AquaSpy platform displays near real-time sensor data to support precision irrigation decisions in organic lettuce research (right).

Figure 2. Organic iceberg lettuce was planted on October 29, 2024, with emergence observed on November 6, at the Valley Research Center, Yuma Agricultural Center, University of Arizona. Photo taken on January 7, 2025. Photo credit: Ali Mohammed.

How Can Sensor-Based Irrigation Scheduling Be Applied to Suppress Weeds in Organic Lettuce Systems? A Tool to "Water the Crops, Not the Weeds"

A key component of precision irrigation is not just how water is delivered, but when and how much is applied. To determine when to irrigate, growers can utilize wireless soil moisture sensors that provide real-time data from different depths in the root zone. For determining how much water to apply, two main approaches can be used. One approach involves using the crop coefficient (Kc) for the specific growth stage of the crop and multiplying it by reference evapotranspiration (ETo) data obtained from the nearest AZMET weather station (https://azmet.arizona.edu/). This provides an estimate of the total irrigation requirement for that stage. Alternatively, growers may rely solely on sensor data by monitoring the soil moisture deficit and applying water to replenish the soil profile to about 90% of field capacity, leaving approximately 10% as a buffer to prevent over-irrigation and surface saturation. This approach promotes efficient water use and helps reduce conditions favorable to weed germination in organic lettuce systems. This approach directly supports the organic farming principle of "feeding and watering the crops, not the weeds." Wireless soil moisture sensors, installed at multiple depths in the root zone, allow growers to monitor moisture dynamics throughout the soil profile through online access to a designated platform. These sensors help ensure irrigation is applied only when necessary, reducing surface wetting via subsurface drip irrigation systems.

When wireless soil moisture sensors are used in combination with SDI systems, sensor-based scheduling provides multiple benefits:

- **Minimizes surface saturation**, thereby reducing opportunities for weed seed germination.
- **Maintains optimal moisture** around the crop root zone, supporting healthy and uniform crop growth.
- **Lowers disease pressure,** as excessive moisture at the surface is also associated with increased incidence of fungal pathogens.
- **Improves irrigation efficiency,** aligning water applications with actual crop evapotranspiration (ETc) and avoiding over- or under-irrigation.

Sensor-based irrigation also allows for dynamic adjusted scheduling. For example, early-season lettuce may need more frequent but lighter irrigation events, while deeper, less frequent applications may be more appropriate as the root system develops. By continuously monitoring soil moisture levels, growers can adjust irrigation in real-time to match crop growth stages and changing environmental conditions. At the University of Arizona, Yuma Agricultural Center, this approach is being applied in ongoing research comparing organic and conventional iceberg lettuce systems under subsurface drip irrigation. Soil moisture sensors are a central component of the experimental design, capturing data at various depths to evaluate how precision irrigation influences weed suppression and overall system performance. This integration of technology and agronomic insight offers organic growers a practical, data-driven strategy to conserve water, reduce labor, and minimize weed pressure over time.

Considerations and Challenges for Adoption

While precision irrigation technologies such as SDI and sensor-based scheduling show promise for improving water-use efficiency and reducing weed pressure in organic systems, their adoption presents practical challenges. According to an electronic survey conducted by Ali Mohammed in 2024 (A. Mohammad, unpublished data), organic growers in the region use a variety of irrigation methods, including surface and subsurface drip, border, furrow, level basin, and sprinkler irrigation. Yuma growers are recognized as pioneers in irrigation management, having developed and refined their practices over generations to match local soils, crops, and environmental conditions. This deep-rooted expertise has contributed to the region's consistently high productivity, particularly in leafy greens like iceberg lettuce. However, transitioning to surface or subsurface drip systems requires a significant shift in both infrastructure and day-to-day management, posing economic, technical, and logistical barriers that must be addressed for broader adoption.

In addition, the adoption of wireless soil moisture sensors requires careful consideration. While these tools provide valuable real-time insights for irrigation management, the initial cost and technical skills needed for installation, calibration, and routine maintenance can present challenges for some operations. Selecting an appropriate sensor that aligns with soil properties and system layout is essential to ensure data accuracy and reliability. Furthermore, consistent data transmission depends on adequate cellular signal coverage—an important factor in regions like Yuma, where connectivity can be limited in certain areas, potentially affecting real-time monitoring capabilities.

Conclusion

Preliminary findings suggest that precision irrigation, particularly subsurface drip systems combined with sensor-based scheduling, have the potential to suppress weed pressure in organic iceberg lettuce systems while maintaining crop productivity. By minimizing surface moisture and aligning water application with actual crop needs, this approach supports the organic principle of "watering the crop, not the weeds." This study is an ongoing, multi-year project, and continued observation is essential to draw robust, long-term conclusions and validate the consistency and scalability of these results.

Disclaimer

This publication provides an objective summary of an irrigation experiment and does not endorse or promote any particular brand, product, or trademark. Any references to product names, trademarks, or companies are included for informational purposes only.

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