

Micro-irrigation and Water Use Efficiency in Horticultural Crops

**Tikam Das Vaishnav¹,
Aakanksha Tiwari²**

^{1&2} Assistant Professor in
Department of Horticulture
RNT College of Agriculture,
Kapasan (Dist.- Chittorgarh)
Mpuat - Udaipur



Open Access

*Corresponding Author
spstarpayal*

Available online at
www.sunshineagriculture.vitalbiotech.org

Article History

Received: 20.08.2025

Revised: 25.08.2025

Accepted: 30.08.2025

This article is published under the
terms of the [Creative Commons
Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

Horticultural crops, including vegetables, fruits, ornamentals, nursery crops, and floriculture, are typically high-value commodities but also highly sensitive to water stress. With agriculture accounting for over 70% of global freshwater withdrawals, the need for sustainable irrigation technologies is urgent. Conventional surface and flood irrigation methods are inefficient, with significant losses due to evaporation, runoff, and deep percolation.

Micro irrigation—comprising drip, subsurface drip, and micro-sprinkler systems—provides precise water application directly to the root zone, enabling optimal soil moisture and crop growth while reducing wastage. Unlike traditional systems, micro irrigation allows integration with fertigation and automation tools, making it particularly suitable for intensive horticultural systems where uniformity, productivity, and quality determine profitability. By improving both water and nutrient use efficiency, micro irrigation contributes to enhanced yields, better product quality, resource conservation, and environmental sustainability.

2. Principles of Micro-irrigation

Micro-irrigation supplies water at low pressure and low flow rates via emitters spaced along lateral tubing or via micro-sprinkler heads. Key system components include a water source, pumping unit, filters, pressure regulators, distribution network (mains, submains, laterals), emitters or micro-sprinklers, valves, fertigation equipment, and control/measurement devices. Two main modes are:

- **Drip/Trickle irrigation:** point emitters (dripline or individual drip stakes) deliver water in drops or small streams into the root zone; available as surface or subsurface installations.
- **Micro-sprinkler irrigation:** low-flow sprinklers deliver a fine spray over a small radius; useful for tree crops, orchards, and some nursery applications to create localized wetting patterns.

3. Water Use Efficiency: Mechanisms & Metrics

Water Use Efficiency (WUE) is commonly expressed as crop yield (kg) or economic value per unit of water applied (m³). Micro-irrigation improves WUE through:

- **Reduction of evaporation losses:** localized delivery lowers the wetted surface area and reduces open evaporation compared with flood or overhead systems.
- **Minimizing deep percolation:** slow application rates match soil infiltration capacity, reducing water lost below the root zone.
- **Improved plant water status:** precise timing and uniformity maintain optimal soil moisture, reducing stress periods and improving crop growth and quality.
- **Enhanced nutrient use:** fertigation places nutrients where roots can access them, increasing nutrient use efficiency and reducing leaching.

Measured gains in WUE vary by crop, climate, and management, but studies typically report yield increases of 10–50% and water savings of 30–70% versus traditional surface irrigation.

4. Design and Management Considerations

Successful micro-irrigation requires careful system design and proactive management.

4.1 Soil and Crop Matching

Soil texture and hydraulic properties determine emitter spacing, application rate, and run times. Sandy soils may require closer emitter spacing or longer run times at lower flows to avoid deep percolation; heavy soils require slower application rates to prevent surface ponding.

4.2 Emitter Selection and Lateral Layout

Emitter types (inline, point, pressure-compensating, non-compensating) influence uniformity and clogging resistance. Pressure-compensating emitters are preferred where elevation or pressure variability exists. Lateral spacing and emitter discharge should ensure overlapping wetted volumes to provide uniform root zone moisture.

4.3 Filtration and Water Quality

Particulate and chemical water contaminants cause emitter clogging. Filtration (sand/media filters, screen filters, disc filters) and chemical pretreatment (acidification, flocculants) are often needed. Water quality parameters—TDS, bicarbonates, iron, manganese, algae, and microbial loads—must be monitored regularly.

4.4 Scheduling and Soil Moisture Monitoring

Irrigation scheduling should be based on crop evapotranspiration (ET_c), adjusted by crop coefficients (K_c), local climate, and soil available water capacity. Soil moisture sensors (tensiometers, capacitance probes, or gravimetric sampling) and plant stress indicators (stem water potential, sap flow) help refine timing to avoid over- or under-irrigation.

4.5 Fertigation and Nutrient Management

Fertigation through drip systems increases fertilizer use efficiency. Fertilizer injection must be done using compatible injectors and with attention to mixing, concentration, and system acidification when necessary. Split applications timed with crop demand reduce nutrient losses and can improve fruit quality and shelf life.

4.6 Salinity and Root Zone Management

Micro-irrigation concentrates salts in the unwetted soil zones; proper irrigation volumes and occasional leaching fractions are required to manage salinity. Subsurface drip can help maintain salts below the active root zone, but careful monitoring is essential.

5. Sensors and Automation — The Role of Smart Irrigation

Integration of sensors (soil moisture, weather stations, leaf wetness, solar radiation) with controllers and telemetry enables precision scheduling and remote control. Automated valves, flow meters, and fertigation controllers reduce labor, detect leaks or blockages, and optimize water and nutrient delivery. Decision support systems that use weather forecasts and ET models further refine scheduling and reduce unnecessary irrigations.

6. Environmental and Economic Benefits

Environmental gains include reduced water withdrawals, lower nutrient runoff, decreased soil erosion, and potential reductions in greenhouse gas emissions per unit production due to higher productivity. Economic benefits accrue from water savings, increased yields and quality, lower fertilizer costs via fertigation, and reduced labor. The payback period depends on system scale, water price, crop value, and access to subsidies or credit.

7. Challenges and Limitations

Despite significant advantages, micro-irrigation systems also face several practical and socio-economic barriers to large-scale adoption:

- **Initial capital cost:** Equipment, installation, and infrastructure setup require high

investment, often unaffordable for small and marginal farmers.

- **Maintenance needs:** Regular filtration, flushing, and inspections are necessary to prevent clogging of emitters and ensure system efficiency.
- **Technical knowledge:** Proper design, irrigation scheduling, fertigation management, and troubleshooting demand training and capacity building among farmers.
- **Water quality constraints:** Saline or sediment-rich water requires treatment, which adds to operational costs.
- **Salinity risks:** Without adequate leaching and management, salts can accumulate in the root zone, adversely affecting crop health and yield.

Addressing these challenges requires strengthening extension services, farmer training programs, innovative financing mechanisms, and development of locally adapted, low-cost technologies.

8. Case Examples and Crop-Specific Notes

1. High-Value Vegetables (Tomato, Capsicum, Cucumber)

- These crops are shallow-rooted and very sensitive to soil moisture fluctuations.
- Drip fertigation ensures a steady supply of water and nutrients at the root zone, avoiding both water stress and excess.
- Improves fruit set, size, and soluble solids (TSS), which directly increases yield and market value.

Example (India): In Maharashtra, drip fertigation in tomato gave 25–35% higher yield with 40–50% water saving compared to flood irrigation.



Fig: In Maharashtra, drip fertigation in tomato

2. Fruit Orchards (Mango, Citrus, Apple)

- Orchards have long crop cycles, and water stress during flowering or fruit setting causes severe yield loss.
- Micro-sprinklers and drip maintain uniform soil moisture, improving fruit size, sweetness, and reducing fruit drop.
- In mango, drip irrigation reduces alternate bearing (year-to-year yield fluctuations).
- Example (India): In Nagpur mandarin (citrus), drip irrigation saved 50–60% water and gave 30% higher yield compared to traditional irrigation.



Fig: In Nagpur mandarin (citrus), drip irrigation

3. Ornamentals and Nursery Crops

- Ornamentals like rose, gerbera, and chrysanthemum require precise irrigation to maintain uniformity and reduce disease incidence.
- Micro-irrigation prevents waterlogging, reduces root rot, and maintains plant health.
- Uniform fertigation ensures even growth in nursery seedlings, improving transplant success.
- Example (India): In Bengaluru's floriculture nurseries, drip irrigation reduced water use by 45–55%, improved flower stalk length, and enhanced vase life.



Fig: In Bengaluru's floriculture nurseries drip irrigation

Summary Table

Crop Type	Preferred Method	Benefits	Indian Example
Vegetables (Tomato, Capsicum, Cucumber)	Drip fertigation	Better fruit set, larger size, higher TSS, reduced blossom-end rot, higher yields	Maharashtra – Tomato yield ↑ 25–35%, water saving 40–50%
Fruit Orchards (Mango, Citrus, Apple)	Drip & Micro-sprinkler	Maintains soil moisture, bigger fruits, reduces fruit drop, less alternate bearing	Nagpur (Citrus) – 30% yield ↑, 50–60% water saving
Ornamentals & Nursery Crops (Rose, Gerbera, Chrysanthemum)	Drip & Micro-sprinkler	Uniform plant growth, fewer root diseases, better stalk length, improved vase life	Bengaluru floriculture – 45–55% water saving, improved quality

9. Practical Recommendations for Growers

1. **Assess water source & quality first:** test for sediments, salinity, pH, iron, and biological contaminants. Match filtration to water characteristics.
2. **Start small, scale up:** pilot a single block or variety to learn management before farm-wide rollout.
3. **Choose appropriate emitters:** use pressure-compensating emitters in uneven terrain or long laterals.
4. **Implement regular maintenance:** flush laterals, backwash filters, and apply chemical cleaning where necessary.
5. **Adopt soil moisture monitoring:** even simple tensiometers provide major scheduling improvements over calendar-based irrigation.
6. **Integrate fertigation:** plan nutrient injections with crop phenology and use water-soluble fertilizers compatible with system materials.
7. **Plan for salinity:** provide occasional leaching events and monitor EC in the soil and drainage.
8. **Seek support:** extension, cooperatives, and manufacturer service programs can reduce learning curves and maintenance burdens.

CONCLUSION

Micro irrigation represents a transformative approach to water management in horticultural production systems. When properly designed, installed, and managed, it enables substantial improvements in water use efficiency, fertilizer utilization, crop productivity, and produce

quality. Environmental benefits include reduced water withdrawals, lower nutrient leaching, and improved soil conservation, while economic benefits include higher returns from increased yield and quality and reduced input costs. However, challenges such as high initial capital cost, need for regular maintenance, technical know-how, and water quality constraints limit large-scale adoption, especially among smallholders. Overcoming these barriers requires targeted extension services, farmer training, credit and subsidy support, and development of low-cost, locally adapted systems. With supportive policies and awareness, micro irrigation can play a vital role in ensuring sustainable horticultural intensification under conditions of water scarcity.

REFERENCES

- Food and Agriculture Organization (FAO). *Drip irrigation for agriculture: A practical guide*. FAO, Rome.
- Postel, S. & Richter, B. *Rivers for Life — Managing Water for People and Nature*. Island Press.
- Keller, J. & Bliesner, R. *Sprinkler and Drip Irrigation*. Van Nostrand Reinhold.
- Pereira, L. S., Pruitt, W. O., & Smith, M. *Irrigation management and scheduling*. Journal of Agricultural Water Management.
- Jensen, M. E. *Design and operation of drip irrigation systems*. Agricultural Engineers.
- Fereres, E. & Soriano, M. A. *Deficit irrigation for reducing agricultural water use*. Journal of Experimental Botany.
- Ayers, R. S. & Westcot, D. W. *Water quality for agriculture*. FAO Irrigation and Drainage Paper.
- Hillel, D. *Introduction to Environmental Soil Physics*. Academic Press.
- Smith, M., & Kelsey, G. *Fertigation and nutrient management in micro-irrigation systems*. Horticultural Reviews.
- Recent review articles on micro-irrigation, fertigation, and precision irrigation in journals such as Agricultural Water Management, Irrigation Science, Horticultural Reviews, and Transactions of the ASABE.