Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 05 (SEP-OCT, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Micro-irrigation and Precision Fertigation: Integrating Water and Nutrient Management for Water-Scarce Agriculture

*Dr. A. R. Ninama[1], Dr. S. D. Chudasama[2] and Dr. K. S. Solanki[3]
[1]Assistant Research scientist, Regional Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhachau, Gujarat- 370140
[2]Scientist, Krishi Vigyan Kendra, Sardarkrushinagar Dantiwada Agricultural University, Tharad, Gujarat- 385565
[3]Assistant Professor, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat- 384460
*Corresponding Author's email: arninama52@sdau.edu.in

Agriculture faces increasing pressure to produce more food with limited freshwater, rising input costs and greater climatic variability. Micro-irrigation, particularly drip and subsurface drip systems, combined with fertigation offers a practical route to deliver water and soluble nutrients near the active root zone. When supported by crop-stage-based scheduling, soil testing and suitable filtration, this approach can improve water and nutrient productivity while reducing avoidable losses. Recent Indian research reports substantial water savings and improved system productivity in selected cropping systems, although outcomes vary with crop, soil texture, climate, irrigation scheduling and equipment management. Emerging sensor-based and Internet of Things (IoT)-enabled systems can further refine decisions by using soil-moisture, weather and crop-status information. However, high initial investment, emitter clogging, water quality, fertilizer compatibility, energy costs and limited technical support remain important constraints. This article reviews the agronomic principles, evidence, practical management and future priorities for precision micro-irrigation and fertigation, with emphasis on water-scarce Indian production systems.

Keywords: drip irrigation, fertigation, water-use efficiency, nutrient-use efficiency, sensor-based scheduling, water-scarce agriculture

Introduction

Water scarcity, erratic rainfall and competition among agricultural, domestic and industrial users make efficient irrigation a central agronomic priority. Conventional surface irrigation can cause uneven distribution, runoff, deep percolation and waterlogging, while broadcasting fertilizer may leave nutrients unavailable to crops or vulnerable to loss. Micro-irrigation applies water in small, controlled quantities through emitters or sprinklers; fertigation introduces suitable soluble fertilizers into the irrigation stream. The combined approach is not simply an equipment change: its value depends on matching water and nutrient supply to crop demand, root distribution and soil conditions (Reddy *et al.,* 2023; Kapoor *et al.,* 2022).

How precision micro-irrigation and fertigation work

Drip irrigation delivers water close to plant roots, whereas subsurface drip places laterals below the soil surface to reduce direct evaporation and keep delivery near the active root zone. A typical system includes a pump, filtration unit, pressure regulator, main and sub-main pipes, laterals, emitters, fertilizer tank or injector, valves and a flushing arrangement. Fertigation allows nutrients—especially nitrogen and potassium, and selected fully soluble formulations of other nutrients—to be supplied in small, timed applications. Fertilizer choice must account for solubility,

water chemistry and compatibility; concentrated products should not be mixed without checking compatibility because precipitation can block emitters.

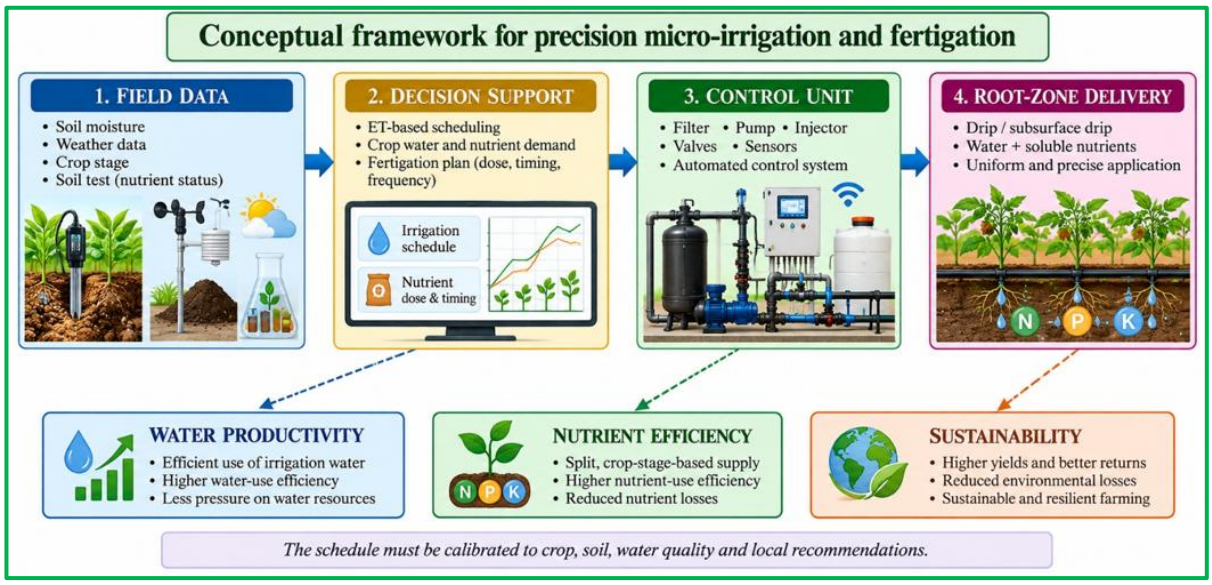


Figure 1. Conceptual framework linking field information, decision support and root-zone delivery in precision fertigation

What recent evidence indicates

Evidence supports the potential of drip fertigation, but percentage gains should be interpreted as study-specific rather than guaranteed outcomes. A 2023 field study of a wheat–mungbean–maize sequence found that surface or subsurface drip fertigation at 0.8 crop evapotranspiration used substantially less irrigation water than conventional surface flooding; the study reported 44.0–58.5% lower irrigation application across the tested seasons and about 20% lower fertilizer use for comparable system performance (Dhayal *et al.,* 2023). A 2024 meta-analysis of studies from China estimated average increases of 31.3% in nitrogen-use efficiency, 34.5% in water-use efficiency and 12.5% in crop yield from drip-based water–fertilizer integration, with outcomes influenced by soil texture, crop type and management (Yang *et al.,* 2024). A recent Indian review also highlights the potential of sensor-supported precision fertigation, while emphasizing investment, data, calibration and farmer-training barriers (Singh & Singh, 2026).

Agronomic practices for reliable performance

First, schedule irrigation using crop evapotranspiration, growth stage, soil moisture and effective rainfall rather than a fixed calendar alone. The most sensitive stages—such as flowering, fruit set and grain filling—deserve careful attention, but over-irrigation should be avoided. Second, base fertilizer quantities on soil testing, crop recommendations and expected yield; split applications according to crop demand instead of assuming that every crop can receive the same fertigation schedule. Third, check pressure and emitter discharge at representative points, clean filters regularly and flush laterals as recommended. Water with high suspended solids, iron or salinity may require specific treatment and more frequent maintenance. Finally, compare costs of equipment, energy, repairs and soluble fertilizers against savings in water, labour and fertilizer and any yield or quality response.

Table 1. Main options and their agronomic use

System	Potential advantage	Key consideration
Surface drip	Precise root-zone delivery; suitable for orchards, vegetables and many row crops	Protect laterals and emitters; check pressure uniformity
Subsurface drip	Can reduce surface evaporation and keep water near active roots	Installation cost, root intrusion and leak detection need planning
Sensor-supported scheduling	Adjusts irrigation to measured soil moisture and weather	Sensors need correct placement, calibration and interpretation
Fertigation	Enables split nutrient supply and can reduce unnecessary application	Use compatible soluble fertilizers; prevent backflow and clogging

Emerging direction: smart and site-specific fertigation

The next step is to connect micro-irrigation hardware with soil-moisture sensors, local weather data, crop-growth observations and automated controllers. Internet-connected systems can alert users to pressure changes, unusual water use or irrigation requirements, while remote sensing may help identify zones with different crop vigour. These tools are most useful when recommendations are validated against field observations and local agronomic guidance. Low-cost, robust systems and simple mobile-based advice may be more appropriate for many smallholders than complex automation. Research should therefore evaluate not only yield and water-use efficiency but also energy demand, system lifetime, maintenance costs, nutrient losses and profitability across seasons (Mohanty *et al.,* 2025; Dass *et al.,* 2025).

Table 2. Practical checklist before and during operation

Action	Why it matters
Test soil and irrigation-water quality	Guides nutrient planning and identifies salinity, sediment or clogging risks
Use crop- and stage-specific schedules	Avoids both water stress and excessive irrigation
Check fertilizer solubility and compatibility	Reduces precipitation and emitter blockage
Inspect filters, pressure and emitter discharge	Maintains uniform application across the field
Keep records of water, fertilizer, yield and cost	Shows whether the system is agronomically and economically beneficial

Constraints and priorities for India

Adoption is limited by upfront capital, fragmented holdings, unreliable electricity, maintenance needs, lack of technical guidance and uncertainty about payback. Subsidies can reduce entry costs, but system design, installation quality, after-sales service and farmer training are equally important. Water saving at plot level also does not automatically guarantee basin-level water conservation if farmers use the saved water to expand irrigated area or grow more water-intensive crops. Programmes should therefore combine efficient technology with groundwater monitoring, crop planning and local water governance. For semi-arid regions such as Gujarat, priority should be given to locally tested schedules, water-quality management, repair services and economic comparisons for crops such as cotton, groundnut, vegetables and orchards.

Conclusion

Micro-irrigation integrated with fertigation can improve the precision of water and nutrient delivery and support more productive agriculture under water scarcity. Its success depends on crop-specific scheduling, suitable fertilizer selection, sound system maintenance and economic evaluation—not on equipment alone. Sensor-based decision support is a promising development, but field calibration, affordability and farmer capacity must remain central. A locally adapted approach that measures water productivity, nutrient-use efficiency, profitability and environmental effects will be essential for scaling the technology sustainably.

References

1. Dass, A., Nithinkumar, K., Singh, A., Sudhishri, S., & Singh, V. K. (2025). Sub-surface drip fertigation for enhanced resource-use efficiency and profitability. *Indian Farming, 75*(12), 45–48.
2. Dhayal, D., Lal, K., Khanna, M., Sudhishri, S., Brar, A. S., Sindhu, V. K., Singh, M., Bhattacharyya, R., Rajath, E., Rosin, K. G., & Chakraborty, D. (2023). Performance of surface and subsurface drip fertigated wheat–moongbean–maize cropping system under different irrigation schedules and nutrient doses. *Agricultural Water Management, 284*, 108338.
3. Govada, D. S., Mrudhula, K. A., Sunil Kumar, M., Ramesh, G., Kishore Babu, G., & Siddarth Naik, B. S. (2024). Effect of salinity and drip fertigation on maize (*Zea mays*) and water use efficiency. *The Indian Journal of Agricultural Sciences, 94*(1), 92–95.
4. Kapoor, R., Kumar, A., Sandal, S. K., Sharma, A., Raina, R., & Thakur, K. S. (2022). Water and nutrient economy in vegetable crops through drip fertigation and mulching techniques: A review. *Journal of Plant Nutrition, 45*(15), 2389–2403.
5. Mohanty, S., Sandal, S. K., Rautaray, S. K., & Sarangi, A. (2025). Drip fertigation for enhancing crop and water productivity. *Indian Farming, 75*(5), 17–20.

6. Reddy, K. S., Nayak, S., Mandi, S., Baral, K., & Shivay, Y. S. (2023). Micro-irrigation: Way forward for precise use of irrigation water in agriculture. *Indian Farming, 73*(2), 18–20.
7. Singh, M., & Singh, K. (2026). Enhancing crop productivity and soil health through precision fertigation: Advancements, challenges and future prospects. *Applied Water Science, 16*, 130.
8. Yang, P., Wu, L., Cheng, M., Fan, J., Li, S., Wang, H., & Qian, L. (2023). Review on drip irrigation: Impact on crop yield, quality, and water productivity in China. *Water, 15*(9), 1733.
9. Yang, X., Zhang, L., Liu, X., et al. (2024). Optimizing water-fertilizer integration with drip irrigation management to improve crop yield, water, and nitrogen use efficiency: A meta-analysis study. *Scientia Horticulturae, 338*, 113653.