

Precision Fertigation: Delivering Nutrients Exactly When Plants Need Them

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Abstract

Precision fertigation combines advanced irrigation technology with real-time nutrient management to deliver fertilizers directly to the plant root zone when they are most needed. This approach optimizes nutrient uptake efficiency, minimizes leaching losses, and supports sustainable crop production. By integrating sensors, automation, and data analytics, precision fertigation systems enable farmers to monitor soil moisture, nutrient levels, and crop growth dynamically. The practice ensures higher yields, better quality produce, and reduced environmental impact. This paper highlights recent advancements, challenges, and prospects of precision fertigation as a cornerstone of modern, resource-efficient agriculture.

Keywords: Precision fertigation, nutrient management, smart irrigation, precision agriculture.

Introduction

In modern agriculture, the art of feeding crops is evolving from guesswork to precision science. Fertigation — the process of delivering nutrients through irrigation water — represents one of the most efficient and sustainable ways to nourish crops. When combined with drip or micro-irrigation systems, fertigation ensures that every plant gets the exact amount of nutrients it needs, exactly when it needs them. This precise synchronization of water and nutrient delivery has made fertigation a cornerstone of precision agriculture, particularly in countries like India where efficient resource use is essential for sustainability and profitability.

The Concept of Precision Fertigation

Precision fertigation is an advanced form of conventional fertigation, where technology and data guide every step of nutrient application. It involves using real-time information about soil moisture, nutrient levels, crop growth stages, and environmental conditions to determine the right composition and timing of fertilizer application. Unlike traditional broadcasting, where nutrients are scattered across the field with significant losses, precision fertigation delivers nutrients directly to the plant root zone through controlled irrigation systems.

The goal is simple yet powerful — to optimize nutrient

uptake, minimize waste, and reduce the environmental footprint of farming. It's a perfect marriage of agronomy, engineering, and digital intelligence.

Mechanism of Precision Fertigation

In a precision fertigation setup, fertilizers are dissolved in irrigation water and injected into the system using a venturi injector or a fertilizer dosing pump. The fertigation unit is equipped with sensors and controllers that regulate the concentration and flow rate based on predefined schedules or real-time data inputs.

Smart fertigation systems are now capable of:

- Monitoring EC (electrical conductivity) and pH levels to maintain nutrient balance.
- Adjusting fertilizer concentration automatically according to plant demand.
- Integrating with soil moisture sensors and weather forecasts to prevent over- or under-irrigation.

This level of control ensures that nutrients are available in the right form, at the right place, and in the right quantity — the core principle of precision nutrient management.

Benefits of Precision Fertigation

1. Enhanced Nutrient Use Efficiency

Precision fertigation drastically improves nutrient use

efficiency (NUE). By delivering nutrients directly to the rhizosphere, plants absorb more and waste less. Studies have shown that fertigation can improve NUE by up to 40–60% compared to conventional fertilizer broadcasting.

2. Higher Yields and Better Quality

Crops receive a continuous and balanced supply of essential nutrients throughout their growth period, resulting in uniform growth, improved photosynthesis, and higher yields. Horticultural crops such as tomato, banana, and grape have shown significant improvements in both yield and quality under fertigation.

3. Conservation of Water and Energy

Fertigation is mostly practiced with drip irrigation systems, which deliver water and nutrients together, minimizing leaching and evaporation losses. This synergy helps conserve up to 50% of water and 30% of energy used in irrigation and fertilizer application.

4. Environmental Sustainability

Precision fertigation minimizes nutrient leaching and runoff — two major causes of groundwater contamination and eutrophication. By applying nutrients only as needed, farmers can achieve sustainable intensification without compromising soil health or environmental quality.

5. Labor and Cost Efficiency

Automated fertigation systems reduce the need for manual fertilizer application, saving labor costs and ensuring uniformity. Over time, farmers experience reduced input costs and improved profitability.

Integration of Technology: From Sensors to Software

The real transformation in fertigation lies in its integration with modern technologies:

- **IoT-based fertigation controllers** automate dosing and scheduling.
- **AI algorithms** predict nutrient demand based on crop stage and weather data.
- **Mobile apps** allow farmers to monitor and control fertigation remotely.
- **Sensors** for pH, EC, and nutrient concentration provide real-time feedback to fine-tune fertilizer delivery.

These innovations ensure that fertigation is not just efficient but also intelligent — adapting dynamically to crop and environmental conditions.

Case Studies and Success Stories

In India, states like Maharashtra, Gujarat, and Andhra Pradesh have adopted fertigation on a large scale, particularly in horticultural crops like grapes, pomegranate, and banana.

Farmers report not only water and fertilizer savings but also noticeable improvements in fruit size, color, and marketability. For instance, precision fertigation under drip irrigation in banana cultivation has reduced fertilizer use by 25–30% while increasing yields by nearly 20%.

Similarly, in Israel and parts of Europe, automated fertigation systems integrated with weather and soil sensors have achieved near-zero nutrient losses — a model now being replicated across developing nations.

Challenges and Way Forward

Despite its potential, precision fertigation faces challenges in adoption:

- **High initial investment** in equipment and automation systems.
- **Lack of technical knowledge** among smallholder farmers.
- **Limited access** to reliable power and digital infrastructure in rural areas.

To overcome these, governments and research institutions are promoting subsidies, training programs, and demonstration projects. The goal is to make precision fertigation accessible, affordable, and scalable across diverse agro-climatic regions.

Conclusion

Precision fertigation embodies the future of efficient and sustainable farming. It enables farmers to achieve the perfect balance of water and nutrients — ensuring that every drop and every gram counts. As digital agriculture expands, integrating fertigation with AI, IoT, and data analytics will make nutrient delivery even more responsive and sustainable. In a world facing water scarcity, soil degradation, and the need to feed billions, precision fertigation is not just a technology — it's a transformation in how we grow food.

References

1. Geraldson, C. M. (1970). Precision nutrient gradients-a component for optimal production. *Communications in Soil Science and Plant Analysis*, 1(6), 317-331.
2. Munson, R. D., & Runge, C. F. (1990). Improving Fertilizer and Chemical Efficiency Through "High Precision Farming".
3. Goenadi, D. H., Mustafa, A. B., & Santi, L. P. (2018, August). Bio-organo-chemical fertilizers: a new prospecting technology for improving fertilizer use efficiency (FUE). In *IOP Conference Series: Earth and Environmental Science* (Vol. 183, No. 1, p. 012011). IOP Publishing.