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Drip Fertigation in Sugarcane for Improving Nutrient and Water Use Efficiency

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Sugarcane is a long-duration, water- and nutrient-exhaustive crop that occupies a central place in tropical and sub-tropical cropping systems, yet conventional flood and furrow irrigation coupled with basal or split surface fertilizer application often results in poor water use efficiency and nutrient use efficiency due to deep percolation, runoff, leaching and volatilization losses. Drip fertigation, the practice of delivering soluble fertilizers directly through a drip irrigation network, offers a precise alternative that synchronizes water and nutrient supply with the crop's growth-stage demand curve. By confining moisture and nutrients to a well-defined wetted root zone, drip fertigation reduces conveyance and evaporation losses, restricts nutrient movement beyond the active root system, and allows frequent, small, split doses that closely track sugarcane's uptake pattern across germination, tillering, grand growth and maturity phases. Field-level evidence across diverse agro-climatic conditions indicates that drip fertigation can save substantial irrigation water and fertilizer while maintaining or improving cane yield, juice quality and commercial cane sugar (CCS) recovery. This article reviews the components of a sugarcane drip fertigation system, the physiological and edaphic mechanisms underlying improved resource-use efficiency, recommended scheduling practices across crop growth stages, and the practical and management considerations that influence adoption and long-term performance.

Keywords: Drip fertigation, sugarcane, water use efficiency, nutrient use efficiency, precision irrigation, fertigation scheduling, commercial cane sugar.

Introduction

Sugarcane (*Saccharum officinarum L.)* is cultivated on more than 26 million hectares worldwide and remains one of the most water- and input-intensive field crops, typically requiring 1,500 to 2,500 mm of water and heavy doses of nitrogen, phosphorus and potassium across its 10–18 month growing cycle. In most traditional production systems, water is applied through furrow or flood irrigation, methods whose field application efficiency rarely exceeds 40 to 50 percent because of deep percolation, tail-end runoff and non-uniform distribution across the field. Fertilizers, particularly nitrogen, are commonly broadcast or side-dressed in two to four splits, exposing a large share of the applied nutrient to leaching, surface runoff and ammonia volatilization before the crop can absorb it. As groundwater tables decline and fertilizer costs rise in many sugarcane-growing regions, there is growing interest in production technologies that decouple yield gains from proportional increases in water and nutrient use. Drip fertigation, which combines localized drip irrigation with the metered injection of water-soluble fertilizers into the irrigation stream, has emerged as one of the most effective such technologies, allowing growers to place both water and nutrients directly in the active root zone in quantities and timings that closely track crop demand.

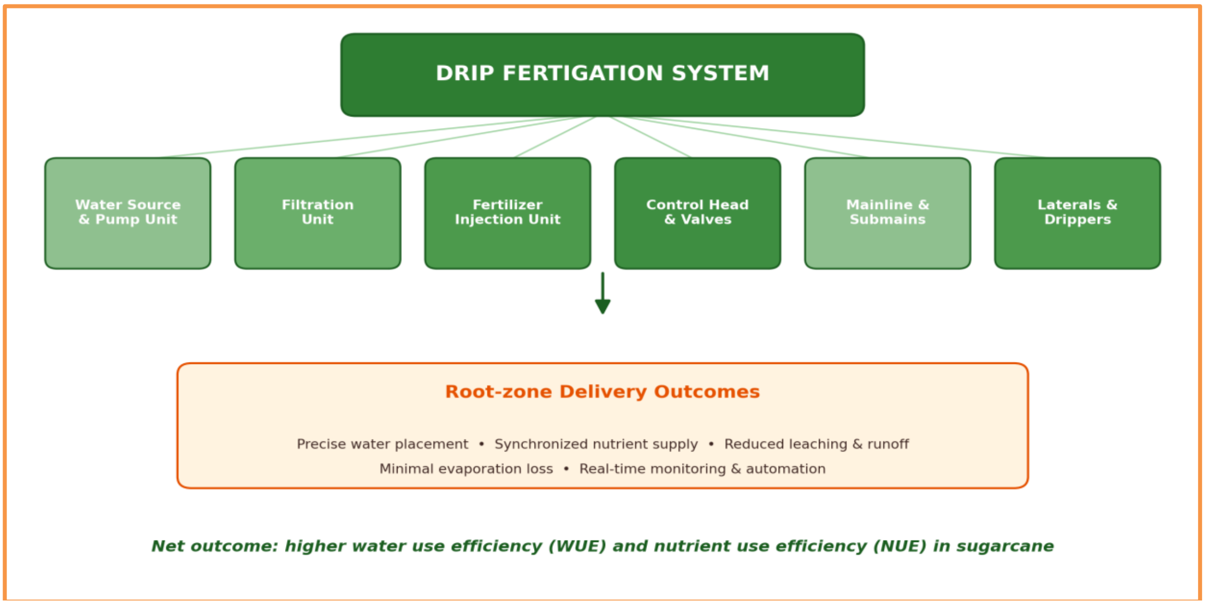

Figure 1. Principal components of a sugarcane drip fertigation system and their combined effect on root-zone resource delivery.

Concept of Drip Fertigation

Fertigation is defined as the application of fertilizers, soil amendments and other water-soluble inputs through an irrigation system, most efficiently through drip or micro-irrigation networks that deliver water in small, frequent doses close to the plant root zone. Unlike broadcast fertilization, where the timing of nutrient availability depends on rainfall or subsequent irrigation to move nutrients into the soil solution, fertigation places dissolved nutrients directly within the wetted bulb around the dripper, making them immediately accessible to actively growing roots. Because sugarcane exhibits a distinct S-shaped nutrient uptake curve, with relatively low demand during germination, a sharp rise through tillering and grand growth, and a tapering demand during ripening, fertigation allows nutrient supply to be shaped to match this curve far more closely than one or two bulk basal and top-dress applications ever could.

Components of a Sugarcane Drip Fertigation System

1. Water Source and Pump Unit – a well, canal, farm pond or reservoir feeding a pump that develops the operating pressure required by the drip network.
2. Filtration Unit – sand separators, screen and disc filters that remove suspended solids and organic debris to prevent emitter clogging.
3. Fertilizer Injection Unit – a venturi injector, fertilizer tank, or electrically driven dosing pump that meters water-soluble fertilizer into the irrigation line at a controlled rate.
4. Control Head and Valves – pressure gauges, non-return valves, air-release valves and flow control valves that regulate and monitor system operation.
5. Mainline and Submains – PVC or HDPE pipes that convey filtered, fertigated water from the control head to the field laterals.
6. Laterals and Drippers – inline or online drip laterals placed along or near the cane rows, delivering water and nutrients directly to the root zone at a controlled discharge rate.

Increasingly, these systems are complemented by soil-moisture and electrical-conductivity sensors, and by simple timer-based or IoT-enabled controllers that automate irrigation and fertigation cycles based on real-time field conditions rather than a fixed calendar.

Mechanisms Improving Water Use Efficiency

- Localized wetting of only a fraction of the field surface substantially reduces the area exposed to direct soil evaporation compared with flood or furrow irrigation.
- Frequent, low-volume applications maintain soil matric potential in the root zone close to field capacity, avoiding both waterlogging and moisture stress cycles.

- Elimination of open-channel conveyance and controlled, low-pressure discharge at each emitter minimizes runoff and deep percolation losses below the root zone.
- Because water is confined to the wetted bulb, inter-row areas remain relatively dry, which also suppresses weed germination and associated non-productive water use.

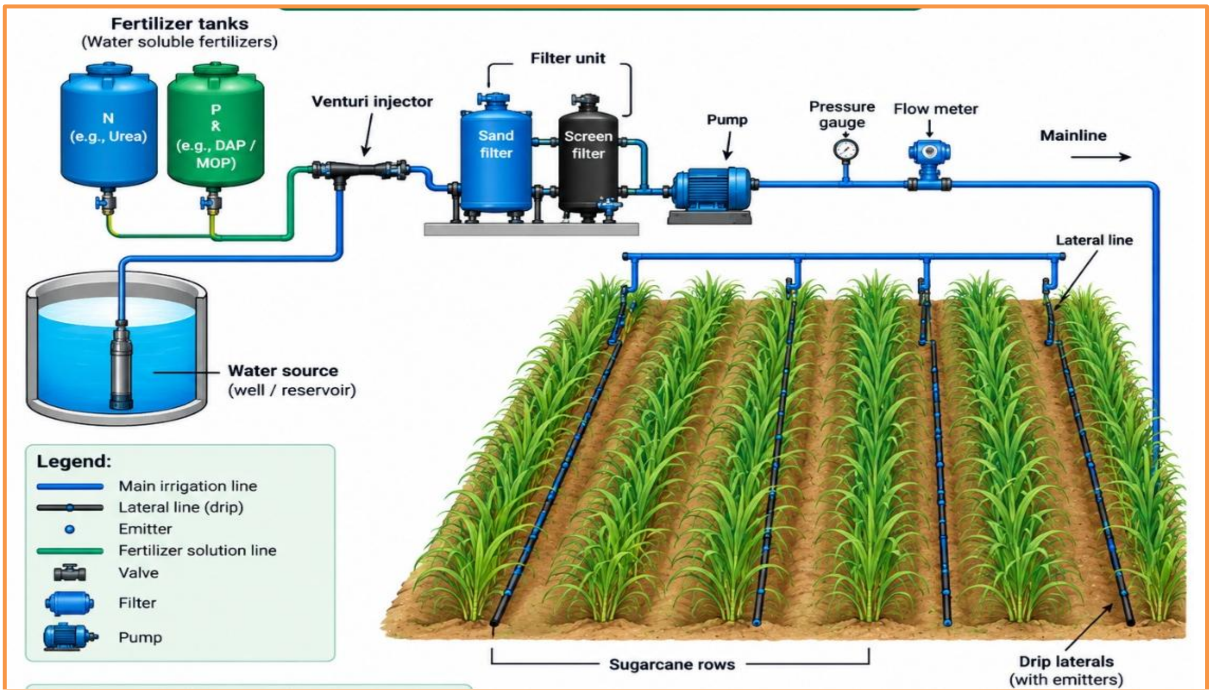

Figure 2. Layout of Fertigation in Sugarcane

Mechanisms Improving Nutrient Use Efficiency

- Split, frequent fertigation matches nutrient release to sugarcane's stage-wise uptake curve rather than relying on one or two large basal or top-dress doses.
- Confining the fertilizer solution to the wetted root zone limits the residence time and travel distance of mobile ions such as nitrate, reducing leaching losses below the effective rooting depth.
- Drip-applied urea and ammoniacal nitrogen are moved into the soil solution immediately, lowering the surface exposure time that drives ammonia volatilization compared with surface broadcasting.
- Localized moist conditions around the dripper encourage a denser, more active root mass in the wetted bulb, increasing the root surface area available for nutrient absorption.
- Reduced soil contact time for phosphatic fertilizers lowers fixation by calcium, iron and aluminum compounds, keeping a larger fraction of applied phosphorus plant-available.

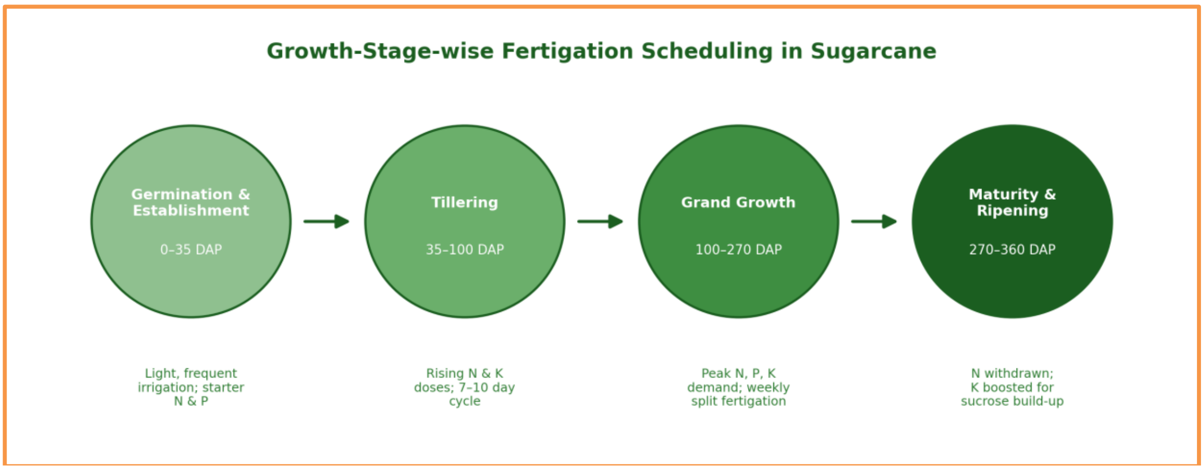

Figure 3. Growth-stage-wise fertigation scheduling windows for sugarcane, from germination through the ripening phase.

Application Methods and Fertigation Scheduling

Sugarcane growth is commonly divided into four broad physiological phases, each with a distinct water and nutrient requirement that fertigation scheduling should follow. During germination and establishment (0 to 35 days after planting), light and frequent irrigation with a modest starter dose of nitrogen and phosphorus supports uniform sprouting and early root development. The tillering phase (35 to 100 days after planting) calls for gradually increasing nitrogen and potassium doses applied on a 7 to 10 day fertigation cycle to encourage profuse tiller production. The grand growth phase (100 to 270 days after planting) coincides with the period of maximum biomass accumulation and nutrient demand, during which weekly split fertigation of nitrogen, phosphorus and potassium sustains rapid stalk elongation. As the crop enters maturity and ripening (270 to 360 days after planting), nitrogen fertigation is withdrawn or sharply reduced while potassium is maintained or increased to favor sucrose accumulation and improve juice quality. Water-soluble grades of urea, mono-ammonium phosphate, muriate or sulphate of potash, and complex NPK fertilizers are generally preferred for fertigation, and care is taken to avoid mixing fertilizers that form insoluble precipitates, such as calcium- and sulphate-bearing sources, within the same injection cycle.

Effects on Growth, Yield and Resource-Use Efficiency

Across a range of soil and climatic conditions, sugarcane grown under drip fertigation has consistently shown deeper and more profuse root systems, higher tiller and millable cane counts, and better stalk girth compared with furrow-irrigated, surface-fertilized crops. Reported water savings from drip fertigation relative to conventional furrow irrigation commonly range from about 30 to 50 percent, while fertilizer savings of roughly 20 to 30 percent have been achieved without any yield penalty, and cane yield increases in the range of 15 to 25 percent have been documented in several field evaluations. Because potassium nutrition can be sustained more precisely into the ripening phase, drip-fertigated sugarcane has also been associated with improved juice quality parameters and higher commercial cane sugar (CCS) recovery in a number of trials. These combined gains in yield and quality, achieved with substantially less water and fertilizer, translate directly into a higher partial factor productivity of both applied water and applied nutrients.

Practical Approaches and Management

1. **Filtration and System Maintenance:** Regular backwashing of sand and screen filters and periodic acid treatment of laterals are essential to prevent emitter clogging from suspended solids, algal growth or chemical precipitates, particularly where source water has high iron or hardness content.
2. **Fertilizer Selection and Compatibility:** Only fully water-soluble fertilizer grades should be used, and growers should verify chemical compatibility before tank-mixing to avoid precipitate formation that can block drippers.
3. **Irrigation Scheduling Tools:** Soil moisture sensors, tensiometers or simple evapotranspiration-based scheduling help fine-tune irrigation frequency and duration to actual crop water demand rather than a fixed calendar, further improving WUE.
4. **System Design and Layout:** Correct dripper spacing, discharge rate and lateral placement relative to the cane row are critical, since a poorly designed wetted bulb can leave part of the root zone under-irrigated even when the system is operating correctly.
5. **Economics and Adoption:** The relatively high initial capital cost of drip fertigation infrastructure remains the principal barrier to adoption for smallholders; subsidy schemes, custom-hiring arrangements and demonstrated payback through water, labor and fertilizer savings are important levers for wider uptake.

Future Prospects

Emerging research is focused on integrating drip fertigation with soil-moisture and canopy-sensor networks to enable automated, demand-based irrigation and nutrient scheduling rather than fixed-interval programs. Subsurface drip fertigation, in which laterals are buried below the soil surface, is being evaluated for its potential to further reduce evaporation losses and surface weed growth in sugarcane. Variable-rate fertigation guided by remote sensing or canopy reflectance indices is also being explored to adjust nutrient dosing to within-field variability in crop vigor. Together with decision-support software and simple mobile-based advisories, these developments point toward drip fertigation evolving from a resource-saving irrigation method into a fully data-driven precision nutrient and water management platform for sugarcane.

Conclusion

Drip fertigation offers sugarcane growers a practical, field-proven pathway to substantially improve both water use efficiency and nutrient use efficiency by delivering water and dissolved nutrients directly to the active root zone in quantities and timings aligned with the crop's physiological demand. The resulting reductions in leaching, runoff, evaporation and volatilization losses translate into meaningful savings in irrigation water and fertilizer while sustaining or improving cane yield and juice quality. Realizing these benefits consistently requires attention to system design, filtration and maintenance, fertilizer compatibility, and stage-wise scheduling, along with continued support for smallholder adoption through training, custom-hiring services and subsidy programs. As water scarcity and input costs continue to rise in sugarcane-growing regions, drip fertigation is well positioned to become a standard component of sustainable, resource-efficient sugarcane production.

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