AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 08 (August, 2026)
Available online at http://www.agrimagazine.in


# Common Fertigation Problems in Protected Cultivation: Causes, Consequences and Engineering Solutions

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Protected cultivation requires precise management of irrigation and nutrients because crop production depends largely on controlled delivery of water and fertilizers to the root zone. Fertigation through drip irrigation provides this control, but its effectiveness can be compromised by poor water quality, unsuitable fertilizers, inadequate filtration, incorrect injection, improper EC and pH management and insufficient system maintenance. These problems can cause emitter clogging, pressure variation, nutrient imbalance and non-uniform crop growth, particularly in intensive crops such as capsicum and parthenocarpic cucumber. This article examines common fertigation-related mistakes from both engineering and crop-management perspectives and provides practical measures for their prevention. Emphasis is given to water-quality assessment, fertilizer compatibility, filtration, injector calibration, pressure management, scheduling, system flushing and routine monitoring. Integrating these practices can improve the reliability and uniformity of fertigation systems and support efficient production under protected conditions.

**Keywords:** Protected cultivation, fertigation, drip irrigation, nutrient management, polyhouse, electrical conductivity, pH, water-soluble fertilizers

## Introduction

In a protected structure, irrigation and nutrient delivery are largely controlled by the grower rather than by rainfall and natural nutrient redistribution. Consequently, errors in irrigation scheduling, fertilizer concentration, filtration or hydraulic operation can directly affect the crop root environment. This makes fertigation management particularly important for high-value crops grown under polyhouse conditions. Since rainfall does not contribute directly to the root zone inside protected structures, irrigation becomes the sole source of water and plays a crucial role in nutrient uptake, plant growth and crop productivity. Drip irrigation is therefore the preferred method because it delivers water directly to the root zone with high application efficiency while minimizing evaporation, runoff and deep percolation losses (FAO, 2013; Keller and Bliesner, 1990; INCID, 2018). A global meta-analysis covering surface and drip fertigation reported average increases of approximately 20% in crop yield, 26% in nutrient-use efficiency and 51% in water productivity compared with corresponding conventional fertilizer-application practices (Delbaz et al., 2023). The performance of a fertigation system, however, depends on proper system design, good-quality irrigation water, efficient filtration, compatible water-soluble fertilizers, accurate fertilizer injection, scientific irrigation scheduling and regular maintenance. Deficiencies in any of these components can reduce application uniformity, resulting in emitter clogging, fertilizer precipitation, nutrient imbalance, salt accumulation in the root zone and uneven crop growth. Such problems are frequently observed in commercial polyhouses cultivating capsicum and parthenocarpic cucumber, where precise water and nutrient management is essential (Keller and Bliesner, 1990; Burt *et al.*, 1998; FAO, 2013; Resh, 2022). With increasing input costs and the growing need for sustainable production, improving nutrient-use efficiency has become essential for profitable protected cultivation. This article discusses the most common fertigation mistakes encountered in protected cultivation, explains their engineering and agronomic implications and presents practical solutions to improve irrigation performance, nutrient-use efficiency and crop productivity.

## Engineering principles of fertigation

Fertigation in protected cultivation can be viewed as a coordinated hydraulic and nutrient-delivery process. The irrigation network must provide adequate pressure and discharge at each emitter while the fertilizer-injection unit introduces the required nutrient concentration into the irrigation stream. Water quality, fertilizer solubility, filtration and operating pressure therefore influence not only nutrient delivery but also the reliability of the complete irrigation network. Any weakness in one of these components can produce clogging, pressure variation or non-uniform nutrient distribution. A typical fertigation system comprises a water source, pumping unit, primary and secondary filters, fertilizer injector (Venturi or dosing pump), mainline, sub-main, laterals and drip emitters. Each component contributes to maintaining application uniformity and reliable system performance. Consequently, periodic inspection, flushing and maintenance are critical for efficient operation.

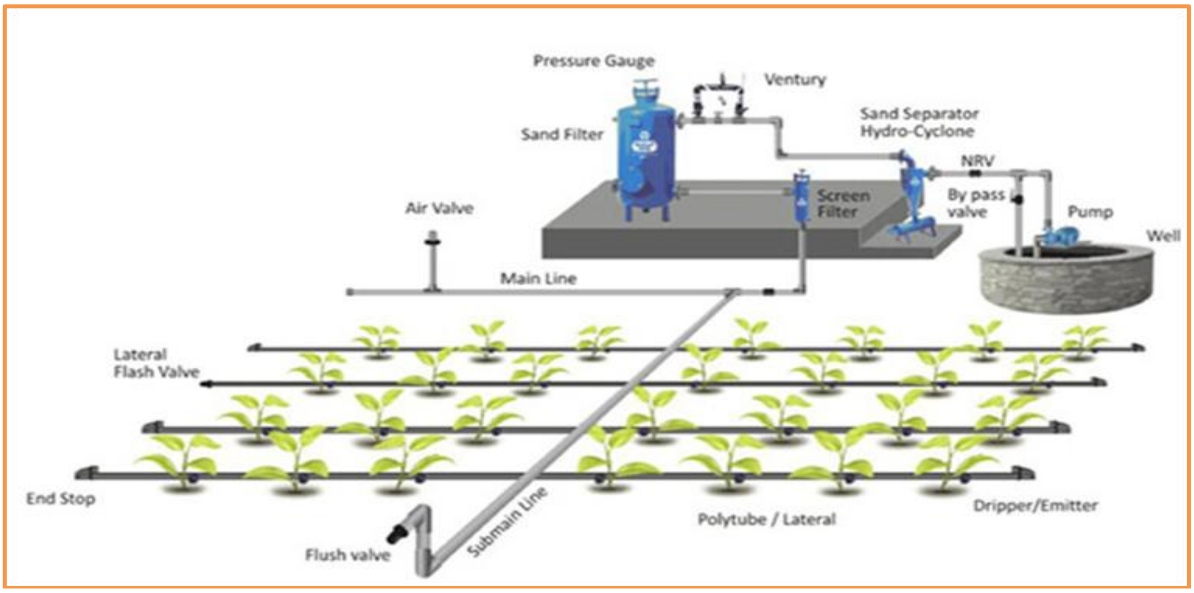


**Fig. 1 Fertigation through drip irrigation system**

***(Source: https://www.agrivi.com/blog/an-efficient-fertilization-and-water-management-with-fertigation/)***

### 1. Fertilizer injection methods

The fertilizer injector determines the accuracy of nutrient application. Venturi injectors are widely used in naturally ventilated polyhouses because of their simple design and low cost, whereas injector pumps and electrical dosing pumps provide higher dosing accuracy and are preferred in automated commercial systems. The choice of injector should be based on the required level of fertigation precision and operational requirements.

### 2. Water quality, EC and pH management

Water quality directly influences fertigation efficiency and emitter performance. High concentrations of suspended solids, bicarbonates, calcium, magnesium or iron may cause fertilizer precipitation and emitter clogging. Therefore, irrigation water should be analysed before preparing fertigation schedules. Electrical conductivity (EC) reflects the concentration of dissolved salts, while pH governs nutrient availability in the root zone. Nutrient-solution EC should be managed according to crop, growth stage, cultivar, climatic conditions and irrigation strategy. Solution pH should likewise be maintained within the range appropriate for the crop and nutrient formulation with regular measurement used to identify deviations before they affect nutrient availability.

### 3. Engineering performance indicators of a fertigation system

The performance of a fertigation system is evaluated not only by crop response but also by hydraulic and operational indicators that determine the uniformity and efficiency of water and nutrient application.

| Parameter | Importance | Indicative Target |
|---|---|---|
| Distribution Uniformity (DU) | Indicates uniformity of water distribution in the field | >85% |
| Emission Uniformity (EU) | Measures uniformity of emitter discharge | >90% |
| Operating Pressure Variation | Maintains equal emitter discharge | ±10% of design pressure |
| Fertilizer Injection Accuracy | Ensures correct nutrient concentration | ±5% of target dose |
| Filtration Efficiency | Prevents emitter clogging | Appropriate filter based on water quality |

*(Source: ASABE (2021); Keller & Bliesner (1990); Merriam & Keller (1978))*

Maintaining these performance indicators through proper hydraulic design, pressure regulation and routine maintenance is essential for efficient fertigation under protected cultivation. The detailed information for obtaining better the aforementioned parameters is given below in the following engineering tables:

**Table 1. Causes of Emitter Clogging**

| Observed problem | Likely mechanism | Diagnostic check | Corrective action |
|---|---|---|---|
| Sediment accumulation | Physical particles entering the network | Inspect filter/sediment load | Improve pre-filtration and flushing |
| White deposits at emitters | Mineral precipitation | Check water chemistry and solution compatibility | Modify fertilizer combination and treatment |
| Slippery/slimy material | Biological growth | Inspect tank and pipelines | Sanitize system and control light/algal growth |

*(Source: Bucks et al. (1979); Nakayama & Bucks (1986); Burt et al. (1998))*

**Table 2. Pressure Variation**

| Pressure Condition | Effect on Emitters | Crop Response |
|---|---|---|
| Low pressure | Reduced discharge | Water and nutrient deficiency |
| High pressure | Excess discharge | Waterlogging and nutrient leaching |
| Uneven pressure | Non-uniform emission | Uneven crop growth and yield |
| Pressure fluctuation | Variable injection rate | Nutrient imbalance |

**Table 3. Recommended Filtration**

| Water Source | Recommended Filtration |
|---|---|
| Open well | Hydro cyclone + Sand Filter + Screen Filter |
| River/Canal | Sand Filter + Disc Filter |
| Farm pond | Sand Filter + Disc Filter |
| Borewell | Screen/Disc Filter (Hydro cyclone if sand is present) |
| Recycled nutrient solution | Sand Filter + Disc Filter + UV/Disinfection (if applicable) |

*(Source: INCID (2018); FAO (2013); Nakayama & Bucks (1986))*

**Table 4. Preventive Flushing Schedule**

| Component | Recommended Frequency |
|---|---|
| Laterals | Weekly |

| Component | Recommended Frequency |
|---|---|
| Sub-main | Every 2–4 weeks |
| Mainline | Monthly |
| Sand filter | Backwash when pressure differential exceeds recommended limits |
| Screen/Disc filter | Clean whenever pressure drop exceeds manufacturer recommendations |

*(Source: Burt et al. (1998); INCID (2018); ASABE (2021))*

**Table 5. Preventive Maintenance Checklist**

| Activity | Frequency |
|---|---|
| Check operating pressure | Daily |
| Measure EC and pH | Daily |
| Inspect injector calibration | Weekly |
| Flush laterals | Weekly |
| Clean filters | Weekly or as required |
| Water quality analysis | Monthly |
| Uniformity test (DU/EU) | Every season |
| Complete system inspection | Before each crop cycle |

*(Source: ASABE (2021); Burt et al. (1998); Keller & Bliesner (1990))*

## Hydraulic considerations for efficient fertigation

Uniform fertigation cannot be achieved if the hydraulic network delivers substantially different emitter discharges along the same lateral. Friction losses, elevation differences, inappropriate pipe dimensions and inadequate pressure regulation can progressively alter emitter discharge and consequently nutrient delivery. Pressure-compensating emitters can reduce this problem within their specified operating range and are particularly useful where laterals are long or pressure differences are expected. Where pressure variation is already small, conventional non-compensating emitters may provide an adequate and economical alternative. Injector calibration should be verified periodically to ensure that fertilizer injection rates match the intended nutrient concentration. Fertilizer injection should generally begin only after the irrigation system reaches stable operating pressure and should stop before irrigation ends so that clean water flushes fertilizers from pipelines and emitters, minimizing salt deposition and clogging.

Routine flushing should maintain sufficient water velocity to remove settled particles from pipelines, thereby preserving hydraulic efficiency and extending system life.

## Common fertigation mistakes: causes, consequences and engineering solutions

### Mistake 1: Using Non-Water-Soluble Fertilizers

| Item | Description |
|---|---|
| Mistake | Application of conventional granular fertilizers or incompletely dissolved fertilizers through the drip irrigation system. |
| Engineering Cause | Low fertilizer solubility results in undissolved particles that accumulate inside filters, pipelines and emitters, reducing hydraulic efficiency and application uniformity. |
| Crop Symptoms | Uneven crop growth, nutrient deficiency symptoms, poor flowering and reduced fruit yield. |
| System Effect | Frequent emitter clogging, increased pressure losses, reduced emission uniformity (EU) and higher maintenance requirements. |
| Practical Solution | Use only high-quality, completely water-soluble fertilizers recommended for fertigation. Prepare stock solutions separately and ensure complete dissolution before injection. |
| Prevention | Verify fertilizer solubility before use, filter stock solutions where necessary and avoid introducing undissolved particles into the irrigation system. |

**Mistake 2: Ignoring Irrigation Water Quality**

| Item | Description |
|---|---|
| Mistake | Using irrigation water without analysing its chemical and physical quality. |
| Engineering Cause | High concentrations of suspended solids, bicarbonates, calcium, magnesium, iron or manganese promote chemical precipitation and physical clogging within the irrigation network. |
| Crop Symptoms | Nutrient deficiencies, poor plant vigour, irregular crop growth and reduced yield. |
| System Effect | Reduced discharge, emitter blockage, non-uniform water distribution and shortened irrigation system life. |
| Practical Solution | Analyse irrigation water before preparing fertigation schedules and adopt suitable filtration and water treatment measures. |
| Prevention | Monitor water quality periodically and adjust fertilizer selection according to water chemistry. |

**Mistake 3: Mixing Incompatible Fertilizers**

| Item | Description |
|---|---|
| Mistake | Mixing fertilizers that react chemically in the stock solution. |
| Engineering Cause | When incompatible fertilizers are concentrated in the same stock solution, chemical reactions can form poorly soluble compounds. These deposits may accumulate in filters, pipes or emitter passages and progressively reduce discharge. |
| Crop Symptoms | Nutrient deficiencies despite fertilizer application, uneven crop growth and poor fruit development. |
| System Effect | Severe emitter clogging, reduced application uniformity and increased maintenance cost. |
| Practical Solution | Prepare separate stock solutions for incompatible fertilizers and inject them independently according to compatibility recommendations. |
| Prevention | Follow fertilizer compatibility charts and conduct a jar test before preparing concentrated stock solutions. |

**Mistake 4: Inadequate Filtration**

| Item | Description |
|---|---|
| Mistake | Operating the fertigation system with insufficient or poorly maintained filtration. |
| Engineering Cause | Suspended particles bypass filters and accumulate in emitters, increasing hydraulic resistance. |
| Crop Symptoms | Patchy irrigation, uneven crop growth and localized water stress. |
| System Effect | Reduced emission uniformity, frequent clogging and increased operating pressure losses. |
| Practical Solution | Select filters according to water source, monitor pressure differential and clean or backwash filters regularly. |
| Prevention | Establish a routine filter maintenance schedule and inspect filtration units before every fertigation event. |

**Mistake 5: Improper EC and pH Management**

| Item | Description |
|---|---|
| Mistake | Failure to monitor or maintain optimum nutrient solution EC and pH. |
| Engineering Cause | Incorrect nutrient concentration or unsuitable pH reduces nutrient availability and may promote salt accumulation or precipitation. |
| Crop Symptoms | Leaf chlorosis, tip burn, blossom-end rot, poor fruit quality and reduced yield. |

| Item | Description |
|---|---|
| System Effect | Nutrient imbalance, inefficient fertilizer utilization and reduced fertigation efficiency. |
| Practical Solution | Monitor EC and pH regularly and adjust nutrient solution according to crop growth stage and recommended limits. |
| Prevention | Calibrate EC and pH meters periodically and maintain routine monitoring records. |

## Best engineering practices for efficient fertigation

Efficient fertigation requires the integration of sound hydraulic design, proper nutrient management and systematic operation and maintenance of the irrigation system. Adoption of the following engineering practices can significantly improve water and nutrient application efficiency while reducing system failures.

1. Use good-quality irrigation water: Analyse irrigation water before designing the fertigation programme. Select suitable filtration and fertilizers based on water quality parameters.
2. Install an appropriate filtration system: Select hydro cyclone, sand and screen/disc filters according to the water source. Monitor pressure differential across filters and clean or backwash them as recommended.
3. Use only completely water-soluble fertilizers: Prepare stock solutions separately, ensure complete dissolution and avoid mixing incompatible fertilizers.
4. Calibrate fertilizer injectors regularly: Verify the injection rate periodically to ensure accurate nutrient application. Recalibrate after repairs or whenever injection accuracy is doubtful.
5. Check pressure at the pump outlet, filter outlet and representative lateral ends to identify losses that may otherwise remain unnoticed.
6. Monitor EC and pH routinely: Measure the EC and pH of irrigation water, stock solutions and drainage water using calibrated instruments. Adjust nutrient solutions according to crop stage and recommended limits.
7. Follow scientific fertigation scheduling: Apply nutrients according to crop growth stage, weather conditions and evapotranspiration demand. Begin fertilizer injection only after stable operating pressure is achieved and finish injection before irrigation ends so that clean water flushes the system.
8. Flush the irrigation system regularly: Flush laterals, sub-mains and mainlines at recommended intervals to remove sediment, precipitates and biofilm. Maintain sufficient flushing velocity for effective cleaning.
9. Inspect the system periodically: Check emitters, filters, valves, pressure regulators and pipelines for clogging, leakage or mechanical damage before this affects application uniformity.
10. Maintain operational records: Record irrigation duration, fertilizer application, EC, pH, pressure readings, maintenance activities and water quality results to facilitate timely diagnosis and long-term system management.

## Troubleshooting guide for fertigation systems

**Table 6. Troubleshooting Guide for Fertigation Systems**

| Problem | Probable cause | First check | Corrective action |
|---|---|---|---|
| Uneven crop growth | Clogged emitters/pressure variation | Measure pressure and emitter discharge at beginning/end of lateral | Flush, clean filters and correct pressure |
| Low emitter discharge | Clogging | Inspect emitter and filter | Clean/flush and treat according to clogging type |

| Problem | Probable cause | First check | Corrective action |
|---|---|---|---|
| Nutrient deficiency | Incorrect EC/pH/injection | Compare target vs measured EC and injector rate | Recalibrate and adjust solution |
| Fertilizer precipitation | Incompatible fertilizers | Conduct jar test | Separate incompatible stock solutions |

*(Source: FAO (2013); Burt et al. (1998); ASABE (2021); Keller & Bliesner (1990))*

## Conclusion

Fertigation has become an important component of protected cultivation because it enables precise application of water and nutrients to the crop root zone. However, its success depends on proper hydraulic design, irrigation water quality, fertilizer compatibility, accurate nutrient injection, scientific irrigation scheduling and systematic maintenance. Most problems encountered in commercial polyhouses arise from preventable engineering and operational mistakes rather than limitations of the technology itself. Efficient fertigation is not merely the application of fertilizers through drip irrigation; it is the integration of hydraulic design, water quality management, nutrient chemistry, irrigation scheduling and regular maintenance. Continuous monitoring of pressure, filtration efficiency, injector performance, EC, pH and application uniformity, together with routine flushing and preventive maintenance, ensures reliable system performance and uniform nutrient delivery. Adoption of scientifically managed fertigation practices can significantly improve nutrient-use efficiency, enhance crop productivity, extend irrigation system life, reduce production costs and promote sustainable protected cultivation.

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