Fertigation: A Tool for Efficient Fertilizer and Water Management

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Fertigation is a method of fertilizer application in which fertilizer is incorporated with the irrigation water by the sprinklers or trickle irrigation systems. Nutrients in a solution are injected in the irrigation water using an appropriate injection device. Fertigation provides essential elements directly to the active root zone, thus minimizing losses of expensive nutrients, which ultimately helps in improving productivity and quality of farm produce. Fertilizer use efficiency is increased from 80 to 90 per cent.

Introduction
Fertigation is a method of combined application of water and plant nutrients effecting saving of both water and fertilizers and simultaneously enhancing yields and quality of crops. This technology has been well developed, tested, fine tuned and adapted both under protected cultivation and large scale field situations for a number of widely spaced low volume and high value crops in Israel, USA, Australia, France, Greece and other developed countries. This was possible due to the development of water soluble fertilizers and liquid fertilizers of various grades, micro irrigation systems, micro sprinklers, micro jets and even sprinklers with E-jets.

In India, since last two decades drip irrigation has received greater attention of both the farmers and the government in view of its well proven advantages in both water scarce and sufficient areas. Studies conducted in India and elsewhere have indicated encouraging results of fertigation technology in potato, capsicum, maize and sunflower, banana and pomegranate. Drip irrigation and fertigation go hand in hand in order to improve efficiency of water and nutrients in crop production. Drip irrigation permits application of fertilizers through irrigation water directly at the site of high concentration of root activity and cause for improving the fertilizer use efficiency in crop production.

The practice of fertigation started commercially in the mid-20th century. The first reported example dates back to ancient Athens (400 B.C.) where city sewage was used for the irrigation of tree groves. Liquid ammonia was probably the first commercially produced liquid fertilizer but in modern fertigation the use of ammonia as the nitrogen source is negligible.
Fertigation was first used in Israel in 1969 for tomato grown on sand dunes in a field experiment (Sagiv and Kafkafi 1976). 80% of the irrigated land in Israel is under fertigation and there is negligible share of fertigation in India.

Vegetable production in Indian agricultural scenario has wider scope for increasing the income of the marginal and small farmers. To be more competitive in today’s market of vegetables, the vegetable growers are looking for new ways to achieve superior quality produce with higher yields than the conventional methods. Presently, the vegetable crop production suffers mainly on the availability of water and nutrients. Therefore, water and fertilizer use efficiency through drip fertigation method can be maximized by the improved techniques introduced.

Nitrogen and potassium based fertilizers are the most commonly applied nutrients by fertigation for vegetable crops. Some formulations of phosphorus and micro-nutrients can also be used if compatible with the irrigation water (pH should be less than 6.5). In addition, because of precipitation problems, special precautions must be made not to mix P fertilizers with calcium nitrate and iron. The limited root zone and the reduced amount of mineralization in the restricted wetted zone are the main reasons for the reduced nutrient availability to the plant. These facts led to the installation of fertigation facilities with almost all applications of MIS (Micro irrigation system).

**Types of micro irrigation**

**Sprinkler irrigation**
- Conveys water from the source through pipes under pressure to the field and distributes over the field in the form of spray of “rain like” droplets.
- More efficient than the surface Irrigation.
- Evaporation losses may be only 2-8 per cent of the total sprinkler discharge.
- Highly suitable for sandy, shallow and steep soils.

**Drip irrigation**
- Water is delivered at near the plant, drop by drop.
- Slow application of water in the form of discrete or continuous miniature sprays through mechanical devices called emitters.
- Efficient method of providing irrigation water and fertilizers near the plants.
- Permits the utilization of fertilizers, pesticides and other water soluble chemicals.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fertilizer use efficiency (NPK)</th>
<th>Fertilizer use efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil application</td>
<td>Drip</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>30-50</td>
<td>65</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Potassium</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 1: Fertilizer use efficiency of NPK with different methods.
Criteria for Selection of Micro Irrigation System

Crop physiology:
- Availability of adequate amount of water during the critical stages of crop growth, spacing of the crop.
- Root system - shallow/deep
- Optimum condition required for germination
- Water requirement at different stages of the crops
- Acceptability of overhead irrigation
- Acceptability of foliar irrigation
- Sensitivity to frost
- Sensitivity to water quality

Soil types:
- Texture for assessing the infiltration rate
- Character whether acidic or alkaline through pH measurement.

Water quality:
- In case of brackish/saline water, crops resitivitity to be checked.
- In case of overhead irrigation, plant leaves sensitivity to be checked.
- In the event of sensittiveness for the overhead irrigation, surface irrigation is the only alternative however due care in maintenance to avoid clogging of the drippers has to be ensured.

Topography of land:
- System to ensure uniformity of water application in uneven/sloppy ground.
- No surface run off takes place after water application.
- Type of vegetative cover on the surface to be irrigated.

Wind velocity:
- Close spacing of the sprinkler in high wind zones.
- Select irrigation time when there is no wind.

Availability of adequate power:
- The system selected should be capable of meeting periodical irrigation requirement with the electricity hours available each day.
- In case of the low voltage situation the system performance should remain unaffected.

Crop and cropping systems:
- Any system installed should meet the irrigation requirement of the entire crop/cropping systems.

Objectives of Fertigation
- Maximize profit by applying the right amount of water and fertilizer.
- Minimize adverse environmental effects by reducing leaching of fertilizers and other chemicals below the root zone.
Methods of Fertigation

**Continuous application:** The total amount of fertilizer is injected at constant rate regardless of water discharge rate.

**Three stages application:**
- Irrigation starts without fertilizers.
- Injection begins when the ground is wet.
- Injection is stopped before the irrigation cycle is completed. Remainder of the irrigation cycle allows the fertilizer to be flushed out of the system for the system cleansing

**Proportional application:**
- The injection rate is proportional to the water discharge rate, e.g. one litre of fertilizer solution is mixed in to 1000 litres of irrigation water.
- This method is simple and allows increased fertigation during the periods of high water demand and when most amounts of nutrients are required.

**Quantitative application:**
- Nutrient solution is applied in a calculated amount to each irrigation block, e.g. 20 litre to block A, 40 litres to block B.
- This method is suited to automation and allows the placement of the nutrients by controlling precisely.

**Other latest technologies developed for fertigation are:**
- Precision Irrigation Technology
- Hydroponics

**Precision Irrigation Technology:** It involves gathering environmental data, conservation of soil and water and method of application of water.

**Soil & Water Management Strategies in Precision Farming**

Precision irrigation provides a means for evaluating a crop’s water requirements and a means for applying the right amount at the right time. A method to save water and energy while increasing crop yield.

**Precision Fertigation:** The use of fertigation or chemigation with site-specific technology.

**Components are:**
- **Global Positioning System (GPS):** GPS provides the accurate positional information, which is useful in locating the spatial variability with accuracy.
- **Geographical Information System (GIS):** is the brain of precision farming system and it is the spatial analysis capabilities of GIS that enable precision farming.
- **Remote Sensing:** The role of satellite remote sensing in precision fertigation is to acquire spatially- and temporally-distributed information to identify and analyze crop and soil variability within fields.
- **Variable Rate Applicator**
Hydroponics: Fertigation represents a natural extension of the hydroponics. Main crops grown by hydroponics are tomatoes, cucumbers, strawberries and flowers. The most common growing medium is tuff (volcanic stone), rockwool and vermiculites.

Advantages of Fertigation

- Improved efficiency in fertilizer use generally 60 to 80 per cent of the recommended dose of fertilizers through water soluble fertilizers has been observed to suffice to secure equivalent yields of crops as obtained with the application of 100 per cent straight fertilizers. Better use of fertilizers through fertigation is due to:
  - Least loss of nutrients through leaching to around 10 per cent as compared to 40 to 55 per cent in the traditional system.
  - Optimization of nutrient balance of N; P₂O₅; K₂O by supplying the desired and required quantities of nutrients directly to the root zone in available forms. Since small amounts are provided at regular intervals rather than giving in one or two big doses only, uptake and utilization of nutrients is very high with fertigation. This is largely accomplished due to maintenance of nearer constant concentration of particular nutrient without undue losses through leaching.
  - Fertigation allows for easy application of water soluble fertilizers of different grades and combinations within the rhizosphere so as to match the physiological needs of the crop at different stages of crop growth for better root development with high P fertilizers initially, for active vegetative growth after establishment with N fertilizers and for crop maturity, flower and fruit development with high K fertilizers at reproductive stages (Shivashankar 1999).
  - High nutrient availability due to maintenance of soil moisture near field capacity under drip irrigation.
  - Unlike in traditional system, there is no damage to root system while top dressing of fertilizers.
  - Fertilizers could be applied as frequently as possible and at those stages of growth where the demand is maximum (Ramachandrappa et al 1993).
  - Considerable savings in the application cost of fertilizers as in plough sole application, drilling or band placement of fertilizers.
  - About 25 to 50 per cent reduction in the quantity of fertilizer applied is possible through fertigation especially in crops which require high dose of fertilizer without affecting the growth and yield.
- Eliminates guess work in fertilizer feed system and avoids serious under feed and over-feed rotations.
- Fertigation can also help in maintaining or improving the physical, chemical and biological conditions of the soil.
Higher water use efficiency and 30 to 40 per cent economy in the use of irrigation due to ferti-
drip in crop production.  
For efficient and uniform distribution of plant nutrients, the irrigation system must fulfill certain  
requirements like:  
- It must be designed correctly to operate efficiently  
- It should ensure complete solubility of the fertilizers without leaving any residues  
- It should supply nutrient solution at constant rate and pressure from the main flow line  

*To get maximum benefit of fertigation, care must be taken while selecting the fertilizer and injection  
equipment and the management and maintenance of the system.*

### Disadvantages of Fertigation

- Uneven nutrient distribution system when the irrigation system is faulty. It leads to over  
fertilization or leaching of nutrients when excess water is applied to crops.  
- Chemical reactions of fertilizer with calcium and magnesium leads to chemical clogging.  
- Phosphatic fertilizers and some micronutrients may precipitate in micro-irrigation systems.  
- Corrosion resistant fertigation equipments are needed.  
- Potential chemical backflow in to water supply source.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Fertilizer</th>
<th>Formula</th>
<th>N-P-K content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urea</td>
<td>CO(NH₂)₂</td>
<td>46-0-0</td>
</tr>
<tr>
<td>2</td>
<td>Ammonium Nitrate</td>
<td>NH₄NO₃</td>
<td>34-0-0</td>
</tr>
<tr>
<td>3</td>
<td>Ammonium Sulphate</td>
<td>(NH₂)SO₄</td>
<td>21-0-0</td>
</tr>
<tr>
<td>4</td>
<td>Calcium Nitrate</td>
<td>Ca(NO₃)₂</td>
<td>16-0-0</td>
</tr>
<tr>
<td>5</td>
<td>Magnesium Nitrate</td>
<td></td>
<td>11-0-0</td>
</tr>
<tr>
<td>6</td>
<td>Urea Ammonium Nitrate</td>
<td>CO(NH₂)₂NH₄NO₃</td>
<td>32-0-0</td>
</tr>
<tr>
<td>7</td>
<td>Potassium Nitrate</td>
<td>KNO₃</td>
<td>13-0-46</td>
</tr>
<tr>
<td>8</td>
<td>MAP</td>
<td>NH₄H₂PO₄</td>
<td>12-6-1-0</td>
</tr>
<tr>
<td>9</td>
<td>Potassium Chloride</td>
<td>KCl</td>
<td>0-0-60</td>
</tr>
<tr>
<td>10</td>
<td>Potassium Sulphate</td>
<td>K₂SO₄</td>
<td>0-0-50</td>
</tr>
<tr>
<td>11</td>
<td>Potassium thiosulphate</td>
<td>K₂S₂O₃</td>
<td>0-0-25</td>
</tr>
<tr>
<td>12</td>
<td>MKP</td>
<td>KH₂PO₄</td>
<td>0-52-34</td>
</tr>
<tr>
<td>13</td>
<td>Phosphoric acid</td>
<td></td>
<td>0-52-0</td>
</tr>
<tr>
<td>14</td>
<td>NPK</td>
<td></td>
<td>19-19-19, 20-20-20</td>
</tr>
</tbody>
</table>

*Source: National Committee on Plasticulture Applications in Horticulture*
Characteristics of Fertilizers for Fertigation

Any fertilizer applied through drip irrigation should have following characteristics:

- High nutrient content readily available to plants
- Fully soluble at field temperature conditions
- Fast dissolution in irrigation water
- No clogging of filters and emitters
- Low content of insolubles (<0.02%)
- Minimum content of conditioning agents and compatible with other fertilizers
- Minimal interaction with irrigation water
- No drastic changes of water pH
- Low corrosives for control head and system

Selectivity and compatibility of fertilizers

- Liquid fertilizers are best suited for fertigation as they readily dissolve in irrigation water.
- When preparing fertilizer solutions for fertigation, some fertilizers must not be mixed together. For example, the mixture of \((\text{NH}_4)_2\text{SO}_4\) and \(\text{KCl}\) in the tank considerably reduce the solubility of the mixture due to the \(\text{K}_2\text{SO}_4\) formation.

Other forbidden mixtures are

- Calcium nitrate with any phosphates or sulfates
- Magnesium sulfate with di- or mono- ammonium phosphate
- Phosphoric acid with iron, zinc, copper and manganese sulfates

Precautions to be taken during Fertigation

- Every emitting point must deliver the same volume of water.
- The material used must be free from deposits or residues and must not cause corrosion of the system.
- Constant operating pressure to facilitate uniform mixing of water and fertilizers.
- Selection of most appropriate fertilizer, injection system and crops to be fertigated.
- Fertilizer injection should not begin until all lines are filled with water and emitters are working.
- Drip irrigation system should be allowed to its working pressure prior to fertilizer injection.
- Fertilizers/pesticides/chlorine should not be injected at the same time.

Constraints for Successful Adoption of Fertigation

The high cost of establishing fertigation systems: Majority of farmers are poor in India.

Clogging of lines: By precipitation of bicarbonates and insoluble di-calcium phosphate, magnesium phosphate and calcium carbonate.

Salt injury: In arid climate mobile nutrient anions due to evaporation such as nitrate and chloride together with cations \(\text{Na}^+\) and \(\text{Ca}^{2+}\) may accumulate around the wet zone on the soil surface.
Nutrient deficiency: On heavy clay soils water ponding may be there, at high temperature anaerobic conditions may cause nitrate N loss by denitrification (Bar Yosef 1999).

Oxygen deficiency: Oxygen might be excluded from the saturation zone when there is continuous supply of water at higher regime in the wet soil volume.

Lack of awareness: Creation of awareness is must to generate demand for any products whether it is micro-irrigation system or water soluble fertilizer.

Conclusion
Fertigation offers an opportunity to optimize crop and vegetable production system with respect to both irrigation and fertilization. It provides variety of benefits to users like high crop productivity and quality, resource use efficiency, environmental safety, flexibility in operations, effective weed management and successful crop cultivation on fields with undulating topography. It is considered eco-friendly as it avoids leaching of nutrients especially N-NO₃. Vegetables have been found responsive to fertigation due to wide spacing nature, continuous need of water and nutrients at optimal rate to give high yield with good quality and high capital turnover to investments. Even though the initial cost of establishing the fertigation system is higher but in long term basis it is economical compared to conventional methods of fertilization as it brings down the cost of cultivation. To get the desired results it requires high management skills at operator level like selection of fertilizers, timing and rate of fertilizer injection, watering schedule as well as the maintenance of the system.

Future Thrust
- Need to develop recommendations for the most suitable fertilizer formulations including the basic nutrients (NPK) and microelements according to local soil type, climate, crops and their physiological stages.
- Need to work on reducing the initial cost of establishment through continuous research and development in technology which suits best to Indian conditions.
- Therefore to make the agriculture sustainable and economically viable and to ensure food and nutritional security of the burgeoning population there is need to promote the fertigation at large scale by the concerned stakeholders.

References