Fertigation for High Productivity and Resource Conservation

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Abstract

Technologies for cultivation of crops have been changing over the years. Adherence to the principles of conservation, high use efficiency and higher productivity with optimum inputs and the very idea of crop production as a business venture; all these are leading to the increased adoption of high technological (high-tech) input delivery mechanisms in Agriculture. Among the different inputs to crop production management of water and fertilizer assume highest priority by virtue of the fact that the country has shortage for both and both are essential for any type of crops. Adoption of drip irrigation results in high productivity besides water conservation. If application of fertilizers is also done through the drip system; then the increases in yield and quality of the produce can be multifold as evidenced for several crops over the years. Fertigation is the technique of supplying dissolved fertilizer to crops through an irrigation system. When combined with an efficient irrigation system both nutrients and water can be controlled and managed to obtain the maximum possible yield of marketable product from a given quantity of these inputs. Therefore it is more or less accepted that generalized fertilizer recommendations can be utilized for fertilization plan for a specific crop and its different cultivars. Nonetheless, fertigation gives a tool to make regional modifications of the fertilizer quanta and timing based on soil and leaf or petiole analysis. A far rapid method of adjustments in the application rate to achieve precision is possible.

Keywords: Drip irrigation, fertigation, productivity, resource conservation

1. Background

A brief mention of the science of fertigation, its role in high tech crop production and its adoption and issues related to adoption are discussed. Few general suggestions to overcome the limitations are also indicated.

Technologies for cultivation of crops have been changing over the years. Adherence to the principles of conservation, high use efficiency and higher productivity with optimum inputs and the very idea of crop production as a business venture; all these are leading to the increased adoption of high technological (high-tech) input delivery mechanisms in Agriculture. The tempo of adoption of high-tech methods has been receiving a shot in the arm by the promotion of such technologies through governmental interventions. The trend of government support to the small farmers to acquire technologies like *drip irrigation* and *fertigation* has been spreading from state to state. Among the different inputs to crop production management of water and fertilizer assume highest priority by virtue of the fact that the country has shortage for both and both are essential for any type of crops. For example, our country with a landmass of 2.4% has only 4% freshwater of the globe to cater to 17% of world population. For the sake of comparison, USA with a population of 4.5% has 7 % land mass and 6% freshwater. The following factors contribute to the need for adopting conservative measures of water and other inputs in agriculture.

- India to be most populous country in next 25-50 years.
- Food Production needs to be doubled to sustain the growing population No increase in available land resources.
- Available land is becoming less productive. India to be water scarce nation by year 2025; (report from INCID or GOI)
- Depleting ground water table due to over-exploitation.
- Increasing competition for water use from non agriculture sectors.
- Adverse effect on food production due to water & land problems.
- Excessive use of N fertilizer and resultant pollution of water bodies.
- Excess irrigation and fertilizer use resulting in soil salinization.

Adoption of drip irrigation results in high productivity besides water conservation. If application of fertilizers is also done through the drip system; then the increases in yield and quality of the produce can be multifold as evidenced for several crops over the years.

Fertigation is the technique of supplying dissolved fertilizer to crops through an irrigation system.When combined with an efficient irrigation system (like drip method of irrigation) both nutrients (type and quantity) and water (volume or rate) can be controlled and managed to obtain the maximum possible yield of marketable product from a given quantity of these inputs.

2. How Critical is Fertigation in Drip Irrigation?

Compared to traditional surface irrigation and fertilizer application systems, fertigation targets a small volume of soil; 20-30% of the total volume of the rhizosphere. With drip irrigation the wetted area called "wetted bulb" and it is here the water and fertilizer are targetted. The size and shape of the wetted bulb depends on soil texture and the type of micro irrigation system used.

Figure 1: Drip line and the wetted bulb in the soil profile (Sandy loam soil) resulting from one dripper.

Because water and minerals are concentrated in the wetted bulb active root growth also takes place here. The combination of soil moisture and nutrients concentrating in the soil in wetted bulb enforces the precision control of crop growth. This is the crux of the drip or micro irrigation technology. However, the anchor roots of the crop may grow out of the wetted bulb and they are functionally different. Bringing together moisture, soil air and mineral ions and absorbing roots into the same *soil region* is the achievement one gets in fertigation technology. This enhances the water use and fertilizer use efficiencies resulting in higher crop yields per unit inputs.

Fine tuning the nutrient supply and matching it with the changing nutrient need of the crop during the different development stages is essentially a *scientific art* and it is made *do-able* by fertigation technology. The input management through this technology forms a large part of the so called precision farming package followed in many states in India.

3. Benefits of drip-fertigation

The comparasion of drip irrigation with the conventional system is given in Table 1.

Table 1: Performance of Vegetable Crops under drip and fertigation (data collected from farmers) fields in a traditionally rainfed area in Andhra Pradesh)

Crop**	Yield under conventional irrigation t acre^{-1}	Yield under drip- fertigation t acre^{-1}
Gherkin	4	7.2-12.0
Baby Corn	1.8	2.6
Tomato Hybrid	14-16	22-28
Potato	6	8.2-10
Sugar cane	26	34
Chilly green	5	12
Chilly red	0.7	1.2

**data from farmers' participated in a precision farming project

4. Fertilizer Application

The main goal of fertilizer application is to meet the crop nutrient demand through maximum uptake of nutrients from a minimum quantity of applied fertilizers thus satisfying the crop needs on a real-time basis and reducing the movement of fertilizer away from the root zone.

4.1. Conventional fertilizer application

- Broadcasting- recommended doses of fertilizer (granular or liquid) are spread over the cropped area.
- Banding-fertilizer is drilled along the row of the criop by the side of the plants.
- Drilling-fertilizer is placed beneath the soil near the seed or the plant with the help of drills.
- Foliar application- Liquid fertilizers are sprayed directly to the aerial parts of the plant.

4.2. Shortcomings of Conventional application methods

- Fertilizer is applied in large quantities
- Applied in 2-3 splits No correct placement in relation to nutrient absorbing root system
- No uniform distribution in the field.
- Fixation of P & K by the soil N from Urea is lost due to improper water management by leaching.
- Soil deterioration by salt accumulation
- Fertilizer use efficiency about 40-50%Nutrients are not present in readily plant- available form.
- Generally fertilizer is not applied as per the physiological stages of crops.

Often, solid fertiliser side-dressings are timed to suit management constraints rather than the physiological requirements of the crop. For example, most farmers will have experienced the dilemma of spreading fertilizer the day before a heavy rain and then wondering how much of the fertilizer is either washed away from the crop in run-off or leached below the root zone.

4.3. Fertigation

Fertilizers are dissolved in water and injected through the drip irrigation system. Nutrients can be applied through a drip or spray system. Concentrations of nutrients and the type of nutrient can be varied as per the requirement of the crop at each stage of its growth.

4.3.1. Advantages of Fertigation

- Increase in yield by 25-30%
- Saving in fertilizer by 25-30%
- Nutrient requirement can be fulfilled as per the physiological demand of the crop at different growth stages
- Predominantly acidic nature of the water soluble fertilizers helps in neutralising salts present in water & soil
- Acidic nature helps in preventing clogging of drippers, as it cleans up the drip system.
- No or less nutrient loss by leaching, fixation & volatilization
- Major & micro nutrients can be applied in one solution
- Fertilizers can be injected as per required concentration
- Saving in time, labour, and energy

Continuous applications of soluble nutrients in very small doses (up to 300 splits for banana or 270 splits for sugarcane) overcome the problems of nutrient leaching and moving away from the root zone.It also reduces compaction in the field, results in the fertilizer being placed around the plant roots (rhizosphere) uniformly and allows for rapid uptake of nutrients by the plant.To capitalise on these benefits, particular care should be taken in selecting fertilizers and injection equipment as well as in the management and maintenance of the irrigation system.

Practice of this technology requires developments in three major areas; 1. Equipments for fertigation, 2. Development and supply of special water soluble fertilizers, and 3. Insight into the nutrient uptake pattern during crop life cycle of each crop species.

4.3.2. Equipments for fertigation

Fertigation as a technology is possible with *pressurized irrigation methods* like drip (drippers, and other micro-emitters like micro-sprinklers, jets and sprayers) and sprinkler systems. In pressurized irrigation there is by definition, pressure within the irrigation net work. Injecting fertilizer solution into such systems requires *generating a pressure differential* to overcome the internal pressure. How can we achieve this without hindering the irrigation flow is the crux of fertigation equipment technology? Several types of equipments are developed over the years with this objective in mind.

The basic equipments are 1. Ventury tube, 2. Fertilizer tank, and 3. Fertilizer pump. Of these, projects like APMIP (Andhra Pradesh Micro Irriagtion Project) introduced fertilizer tank as compusory component of drip irriagtion and this has become more popular. And easy to operate at farm level. The ventury tube (1” or 1.5” diameter) is also a simple device and easy to operate.

4.3.3. Fertilizer tank

Fertilizer tanks are made of corrosion resistant, epoxy coated galvanised cast iron, stainless steel or fibreglass with a capacity to withstand the working pressure of the irrigation system.

Pressure differential is created by decreasing the water flow in the main pipe at head control and diverting a fraction of the water through the tank containing the fertilizer solution.

4.3.4. Fertilizer tank follows a flow- bypass principle

- Part of the irrigation water is diverted from the main line to flow through a tank containing the fertilizer in solution before returning to the main pipe line.
- The pressure in the tank and the main line is the same, but a slight drop in pressure is created between the offtake and return pipes by means of a pressure reducing (throttle) valve.
- This causes water from the main line to flow through the tank causing dilution, and flow of the diluted fertilizer into the irrigation stream.

In the above schematic diagram, by adjusting the Choke valve

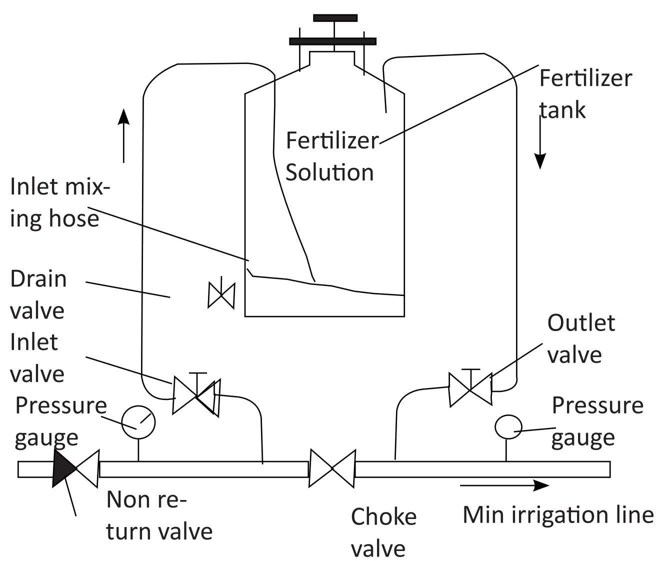

Figure 2: Schematic drawing of fertigation using a fertigation tank in a drip irrigation system

(Throttle valve) a gradient of 0.2 to 0.3 kg pressure will be created between the inlet (entry of system flow into the FT) and outlet (exit of fertilizer carrying water out of the FT) to allow suction of fertilizer solution from the tank.

4.3.4. Fertilizers for fertigation

There is a large range of chemical fertilizers offered for fertigation. Nonetheless, the suitability of a fertilizer for fertigation depends on several of its properties; especially its soloubility in water.Solid fertilizers completely soluble in water at field ambient temperature are suitable for fertigation. Most conventional fertilizers that are soluble and several specilised fertilizers in water soluble form are available at present for fertigation.

Table 2. Conventional fertilizers for fertigation

Common Fertilizers suitable for Fertigation		
Nitrogen	Urea	46-0-0
	Ammo Nitrate	23-0-0
	Ammo Sulphate	21-0-0
Phosphrous	Phosphoric Acid	0-61-0
	Mono Ammo Phosphate	12-61-0
Potassium	Potassium Chloride	0-0-62
	Potassium Nitrate	13-0-46
	Potassium Sulphate	0-0-50
	Mono Pot.Phosphate	0-52-34

Table 3: Special grade Water Soluble fertilizers for fertigation

Water Soluble Fertilisers	N-P2O5-K2O
1. Poly Feed(Haifa)	19-19-19 + TE **
2. Maha Feed	
a. NPK fertiliser	19-19-19 + 1MgO+TE
	20-10-10+ 1MgO +TE
	16-8-24 + 1MgO + TE
b. Potash fertiliser	00-00-50+18S and
Potassium Nitrate	13-00-45
Potassium Sulphate	0-0-50
c.Phosphorus Fertilisers	
Mono Ammonium Phosphate	12-61-00
d. Calcium Nitrate (Granular)	15.5 - 0-0+18.8 Ca

** TE – trace elements (micro nutrients)

4.3.5. Nutrient dosage and scheduling of fertigation

Unlike the above two requirements which are of material science the third aspect is information or knowledge. This is where efforts in India are woefully lacking.

A scientificaly prepared fertigation plan allows coordination of nutrient supply with changing demands of the growing crops. Fertigation planner requires following information to prepare this schedule- *which, when and how much* plan:

- ➢ Crop growing cycle with development stages and their duration
- ➢ How the crop growth cycle is influenced by local climate.
- ➢ Amount of each nutrient required at each stage.
- ➢ Nutrient removal pattern of the crop from the soil or media.

4.3.6. Nutrient uptake at any one time in a crop cycle depends on

- ➢ Crop characteristics
- ➢ Expected final yield
- ➢ Nutrient content in the harvested part and the residual biomass
- ➢ Environmental conditions- temperature, humidity and light.
- ➢ Soil nutrient status (for soil grown crops)

Considering all these factors, specific nutrient recommendations for a crop have to be based on nutrient uptake measurements under conditions as near as possible to those in which the crop is grown. However, this is not always possible especially in the innumerable villages located in large districts of several states of the country. Oftentimes the nearest location from where a recommendation is made can be 400-500 km away from a farm where the crop is grown.

Therefore it is more or less accepted that generaliszed fertilizer recommendations can be utilized for fertilization plan for a specific crop and its different cultivars. Nonetheless, fertigation gives a tool to make regional modifications of the fertilizer quanta and timing based on soil and leaf or petiole analysis. A far rapid method of adjustments in the application rate to achieve precision is possible.

Often the effect of environmental factors is grossly underestimated. For example, the timing and quantities of N, P, and K needed for tomato crop are very different in green house from those in open field conditions.

A solution to this issue is use of leaf analysis at various stages of the crop and making real time adjustments in the nutrient application based on the data. Table 4 illustrates the normal nutrient concentrations in a tomato crop as odbtained from leaf analysis.

Fertigtaion schedule normally prepared from the local fertilizer recomendastions should be adjusted from time to time by:

- ➢ Making regular observation of the crop
- ➢ Identifying any symptoms of nutrient deficiency
- ➢ Analysing the leaf or petiole and recalibrating the fertilizer

Table 4: Normal nutrient concentrations in trellised tomato (youngest full mature leaves were analysed)

N (% of dry wt.)	2.5-4.0	Cu (ppm in dry matter)	5-10
P	0.3-0.6	Zn	30-40
K	3.0-4.0	Mn	50-100
Ca	0.5-2.0	Fe	100-300
Mg	0.6-1.0	B	30-100
		Mo	0.4

quantity and type in the fertilizer program.

- Adjusting also for any season elongation or change in the developmental phase of the crop.

It is also to be noted that many of the conventional beliefs regarding fertilizer dosage and timing have changed in major crops- Tomato, Capsicum, Banana, Sugarcane after the introduction of fertigation and detailed study of nutrient requirements or removal by crop. This aspect is considered as the collateral technology change associated with the spread of drip technology.

4.3.7. A typical case of arriving at a fertigation schedule is described below.

Crop : Sugarcane

Crop duration : 11 months to harvest.
Duration of fertigation : 265 days
Recognised growth stages and developmental phases: Seedling phase; Tillering Phase; Grand growth phase and Maturity phase.

Total quantum of fertilizers are determined 1) Using local fertilizer recommendation or 2) by estimating fertilizer requirement for target yield using nutrient removal data avaiulable in the literature.

Scheduling

Factors considered: total quantum of each fertilizer; Nutrient need (type and quantum) of each physiological stage.

In this case, the fertilizer quanta is determined by either one of the above two methods utilized to make the fertigation schedule. These are then split into many small doses following the upatake curves published after scientific studies. Based on the figure the NPK doses and their ratios are arrived at each stage of cane growth.

For Example, Sugarcane Fertigation where only N and K are fertigated;
Once the ratios are established the fertigation doses are a function of total no of applications. The application schedule is on alternate days is recommended to get maximum fertilizer use efficiency.

To establish similar nutrient demand ratios and their changes parrallel to the crop developmental changes for the crops that we grow and come up with precision fertigation schedules a lot of information has to be generated by research. Here there is a vast area waiting to be tapped by researchers.

5. Fertigation Scenario in the Country

In general the adoption of fertigation was poor in India.

Table 5: A model fertigation schedule where only N and K are fertigated and P is applied to the soil

Location - South Gujarat		Dosage (100 Kg N, 50 kg P and 50 kg K acre^{-1})			
Stage of crop	duration	fertilizer	Quantity kg acre^{-1})	Nutrient %	Total Kg
Basal P	At planting	SSP for 50% P	25	16	156.25
		Urea	100	46	217.4
		MOP	50	60	83.33
At final Earthing up	At Earthing up	SSP for (balance 50% P)	25	16	156.25
Fertigation of N and K					
Development stages	N	K (Ratio)			
Seedling stage	3	1		93.17	12.82
Tillering stage	1	1		31.06	12.82
Grand Growth period	2	1		62.11	12.82
Maturity stage	1	3.5		31.06	44.87
Total				217.39	83.33

Besides extension training of farmers by Private companies providing Agronomic services, implementers of projects like AP Micro irrigation project (APMIP) and other Special Purpose vehicles are advising the farmers to practice fertigation in order to get maximum return from the drip fertigation system that were established. These projects envisage certain benefits to accrue to the participating farmers;

- Increased crop productivity
- Improved quality of produce
- Conservation of water and sustainable use of water
- Higher energy efficiency in agriculture sector
- Higher fertilizer use efficiency and saving in fertilizer
- Saving in labour expenses

There is very little data on the extent of actual adoption of fertigation. A systematic survey is called for assessing the actual adoption of this very useful technology.

Why fertigation is not getting the adoption rate it deserves; this is mainly because of three factors: 1. in the past; fertilizer injectors are not provided as part of drip system and farmers are not informed about this provision and 2. Because of insufficient information and awareness among the farmers those injectors are not put into use wherever they were provided as part of the system and 3. Availability of water soluble fertilizers is limited and their costs are very high. However there are exceptions like almost all the grape growers of Nasik, Maharashtra have been using fertigation systems for a number of years.

Again, as for fertilizer type, it is mainly urea, because of its easy availability and solubility in water that most growers use for fertigation. Specialised fertilizers (water soluble solids) are not popular as one would anticipate them to be.

This may not mean that all the farmers who have installed a fertigation unit are adopting the technology. Though 95% drip systems are accompanied by fertigation equipments in AP, a random survey indicates that only 35% of the reciepients are actaullay fertigating their crops. Farmers are too unfamiliar with the technology itself, it is bound to take time before 100% adopts fertigation. Training and awreness creation is of very critical importance for this technology to get full acceptance. The government and the service providers are taking up programs and training farmers in all aspects of high-tech cultivation including fertigation.

6. Why Adoption of Fertigation in the Country is Slow?

- Fertigation Equipment need additional pressure of 0.5 kg cm^{-2} over and above the operating pressure of drip systems; calling for more HP in the motor
- In most drip system installations in India farmers use their existing low-head high discharge pumps with which adequate pressure for the system itself is not available
- Scientific information on fertilizer requirement rates as a function of growth stages of crop varieties is not available. Such data when available are mostly not tested adequately for more regular need based applications of fertigation
- Conventional fertilizer applications are still based on broad recommendations but not field specific i.e., not based on available nutrient status. So farmers are more comfortable to continue with their broadbased application programs and do not come forward to follow more elaborate fertigation schedules
- In the absence of such information on growth based nutrient requirements of plants, information from research in other countries which is not exactly relevant for our soil conditions, is being used.
- Solubility of most of the conventional fertilizers is not adequate for trouble free fertigation
- Dependence on costly imported liquid or water-soluble fertilizers deters farmers from adopting fertigation
- Manufacture of Water Soluble fertilizers has not taken off fully in India due to regulations and restriction
- in movement of fertilizers in the Fertilizer Act
- The suppliers of imported Water soluble fertilizers have not penetrated into rural areas of several states

6.1. Solutions

- Education and training of farmers in the use of the technology
- Demonstration through KVK's and other public organisation
- In country manufacturing of water soluble fertilizers (see below)
- Development of distribution net work for such fertilizers
- Research (see below) into the science of fertigation
- A model of PPP based intervention to make this technology spread among Indian farmers.

7. Research in Fertigation in India

Recommendations for fertilizer application and rates available in the country are based on research done in the ICAR system or Agricultural universities. One would clearly understand the intricacies and location specificity of such recommendations. As for fertigation, research into different aspects of the technology is still in infancy. Only 3 agricultural universities in the country and IARI, Delhi have been into this area of research. Involvement of more and more universities and ICAR institutions are the need of the hour. Similarly research in the private sector (irrigation and fertilizer and seed companies) is little and often not getting the reach it should get.

8. Manufacture and Supply of Special Grade Water Soluble Fertilizers

There is an urgent need of manufacturing water soluble fertilizers indigenously in the country and ensuring its supply through distrbution and dealer net work. The present scenario of few distributors importing and supplying from limited locations of these valuble input for precision farming can not continue. The high cost and lack of availability of these specialised fertilizers act as deterrents for large scale adoption of fertigation. Why should Indian farmer lose the opportunity for high productivity and higher net incomes??

9. Conclusion

Among the different inputs to crop production management of water and fertilizer assume highest priority by virtue of the fact that the country has shortage for both and both are essential for any type of crops. Adoption of drip irrigation results in high productivity besides water conservation. If application of fertilizers is also done through the drip system; then the increases in yield and quality of the produce can be multifold as evidenced for several crops over the years.

