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FERTIGATION: A CONTEMPORARY STRATEGY FOR BOOSTING OUTPUT: A REVIEW

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ABSTRACT

The most efficient method for optimizing fertilizers and water is through fertigation, particularly with drip irrigation. Drip irrigation targets the active root zone, minimizing the wetting area and maximizing water and nutrient utilization. By integrating fertilizers with drip irrigation, costs for both irrigation and fertilizer application decrease. The national goal is to double farmers' incomes by enhancing yield per unit of water and preserving soil health. Drip-fertigation has emerged as a highly effective technique, ensuring crops utilize resources judiciously. There's a significant emphasis on advancing drip-fertigation methods due to their positive impact on crop responses and yields. Studies confirm that drip-fertigation triples crop yields while improving quality, enabling farmers to command higher prices. Given the increasing food demand and dwindling water supplies, there's pressure to innovate agricultural practices. Drip irrigation, if properly planned and managed, can enhance yields and quality while conserving up to 50% of water compared to surface irrigation. Fertigation, the application of fertilizer and water, boosts production and fertilizer efficiency, minimizing nutrient leaching. To employ fertigation effectively, one must consider nutrient and water consumption rates, crop responses to soil conditions, soil water potential, nutrient concentrations and root distribution across different irrigation regimes and soil types.

Key words : Fertigation, Drip irrigation techniques, Fertilizer use efficiency, Water use efficiency, Water saving, Yield.

Introduction

In agriculture, water and fertilizers are two crucial inputs, improving production and maintaining excellent environmental conditions require effective water and nutrient management (Roma and Kaushal, 2014). Agricultural systems aim to increase crop yield and quality while lowering production costs and ensuring long-term sustainability (HAUCK, 1984). An appropriate and balanced water and nutrient supply is a requirement for attaining this goal. Water and nitrogen fertilizers have significantly increased crop productivity, particularly in cereal crop yields, and will continue to be essential components of the science-based farming necessary to feed the world must growing global population (Kakraliya *et al.*, 2018). Prior to 1989, developed countries consumed more nitrogen fertilizer than developing nations, however after that point, while a real decline in developed nations was noted, the rising tendency for poor nations persisted (Ladha *et al.*, 2016; Bijay-Singh and Ali, 2020, 2020a). In the early 1970s, India accounted for only 5% of the world's fertilizer N usage; but, as of 2015, Indian farmers have been consuming about 16% of it. India consumed 18.86 Mt of fertilizer N in 2019 (FAI, 2019; FAOSTAT, 2020). The percentage of worldwide fertilizer N utilized in India has increased almost linearly, showing that India is consuming fertilizer N at a quicker rate than the rest of the globe.

Similar to fertilizer, the same pattern was seen for groundwater. Groundwater is necessary for agricultural growth, food production and lowering the risk of drought

(Cetin and Akalp, 2019). Over 70% of water is used by irrigated agriculture worldwide (Khokhar, 2017; Anonymous, 2019a). Improvement in water use efficiency is necessary to boost water use effectiveness and switch to a more sustainable use of water in agriculture (Barua, Kumar and Singh, 2018). Use of water-efficient irrigation systems, proper irrigation scheduling, development of watershed management, cultivation of drought-tolerant crops, dry farming, rotational grazing, use of mulch and compost, cover crops, conservation tillage and organic farming are all methods that can be used to achieve this goal. In irrigated agriculture, a sizeable amount of water is lost due to leakage and/or evaporation during storage and transportation to the fields where the crops are grown.

A kind of pressure to develop new technologies for the efficient use of water and fertilizer for agriculture has been created by rising food demand and declining water resources. Other essential factors to take into account include environmental sustainability as well as the preservation of soil and water resources. Therefore, using water and fertilizer efficiently and sparingly is crucial for protecting the environment (Hagin *et al*., 2003). In contemporary irrigated agriculture, fertilization has become a standard practice. Higher water and fertilizer use efficiency is made possible by localized irrigation methods like drip irrigation. This approach, which is a form of current technology, offers numerous advantages over conventional fertilizing. For the production of crops and fruit orchards around the world, combined irrigation and fertilization has therefore been widely adopted (Yan, Dai and Jia, 2018). Applying fertigation is more suited to drip irrigation. Thus, irrigation systems can be used to apply soluble nutrients to moist soil zones at whatever concentrations required by crops (Chartzoulakis and Bertaki, 2015). It is imperative to make every effort to decrease water and fertilizer waste in order to increase their efficiency.

In today's crop production, drip irrigation technique fertilization is gaining more traction. The wetted root volume zone, where the majority of the active roots are concentrated, can be applied the proper amounts of plant nutrients uniformly through fertigation, which contributes to improving nutrient usage efficiency. It has been discovered to increase crop productivity and crop quality while also increasing resource usage efficiency (Jat *et al*., 2011). Fertigation, a synergistic strategy, reduces fertilizer costs by up to 25% (Vaishnava *et al*., 1995). When applying fertigation, it is crucial to take into account the crop stage, the demand for nutrients, the amount of fertilizer to be applied, and the timing of application. By doing this, one can increase water and nutrient efficiency, increase yield and generate financial gains.

Fertigation

Fertigation is the process of applying water soluble fertilizers to crops directly in the field using irrigation water. This method of supplying soluble plant nutrients directly to the active plant root zone is effective and agronomically sound. Fertigation lowers application costs and enables more effective fertilizer and irrigation utilization. It enhances nitrogen uptake and plant growth while reducing nutrient losses. Fertilizer application timing, volume, and concentration can all be easily managed with fertigation. While granular or dry fertilizer application typically results in absorption rates of 10 to 40%, fertilization allows the landscape to absorb up to 90% of the applied nutrients. Fertigation guarantees fertilizer savings of between 40% and 60% because of "improved fertilizer use efficiency" and "reduced in leaching" (Kumar and Singh, 2002). It is carried out with the help of injectors, which are special fertilizer equipment put at the system's head control unit before the filter. Fertilization using a drip irrigation system lowers N-volatilization and leaching losses, increasing the effectiveness of nutrient utilization.

Fertigation, a new agro-technique that combines irrigation with water and fertilizer application, gives a good opportunity to enhance productivity while reducing pollution (Magen, 1995; Shani *et al*., 1988; Sneh, 1987). Fertigation has been discovered to be one of the most effective methods for supplying water and nutrients to drip irrigation systems. Several researchers have indicated that the drip irrigation technique has several advantages (Deshmukh and Hardaha, 2014; El-Hendawy *et al*., 2008; Feleafel and Mirdad, 2013 and Vijayakumar *et al*., 2010). It conserves water, machinery and labour, improves fertilizer application accuracy and uniformity, and increases nutrient uptake by roots. Fertigation, according to Hagin *et al*., (2002) is a modern agro-technique that offers an outstanding potential to maximize productivity while reducing pollution.

The time, amount, concentration, and ratio of nutrients may all be easily managed in a fertigation system. Crop yields and quality are higher as a result of this improved control than with a simple fertilizer application. Fertigation is a technique that can be used with any irrigation system. Fertilizers used with an open irrigation system, on the other hand, can cause unequal nutrient distribution throughout the field. For fertigation, pressurized irrigation systems such as drip, sprinkler, and micro sprinklers are ideal. Mainly drip irrigation system is used for fertigation process.

Depending on the physicochemical characteristics, a wide variety of Fertilizer products are acceptable for fertigation. Sources of solid Fertilizer are usually less costly. When choosing Fertilizers for fertigation, there are four primary aspects to take into account: soil conditions, plant type and stage of growth, water quality, and Fertilizer availability and cost (Kafkafi and Tarchitzky, 2011). Fertilizers with high purity, solubility, low salt content, and an appropriate pH should be chosen, and their cost must be compatible with the farm management programme (Sureshkumar *et al*., 2016).

History of fertigation

The first documented instance of fertigation was in ancient Athens (400 B.C.), when city sewage was used to irrigate tree gardens. Fertigation as a business practice began in the mid-twentieth century. Although liquid ammonia was arguably the first commercially produced liquid fertilizer, ammonia is rarely used as a nitrogen source in current fertigation (Shukla *et al*., 2018). Fertigation is an important aspect in modern intensive irrigated agriculture and its origins may be traced back to the creation of soil-less culture, often known as hydroponics. In the Netherlands, fertilizers have been applied to glasshouses with irrigation water since the early 1950s. Mixing fertilizers with irrigation water was used on a small scale in surface, flood and furrow irrigations in the United States in the mid-1950s. Gaseous ammonia, aqua ammonia, and ammonium nitrate were used as fertilizers. In the early 1960s, in Israel, the development of fertigation technology was parallel to the development and introduction of micro-irrigation. For the precise application of nutrients, electrical pumps and mixing tanks were designed. When fertilizer tanks were employed, nutrient distribution through fertigation was first inconsistent. Later, when venturi suction pumps and fertilizer injectors were used, a more uniform distribution was attained. Fully computerized fertigation units provided much more significant gains (Shukla *et al*., 2018).

Needs of Fertigation

Fertigation is not an option when using pressurized irrigation systems; it is a need. Because only around 30% of the soil is wetted by drip irrigation without fertilization, fertilizer efficiency suffers because nutrients aren't dissolved in the dry zones where the soil isn't wetted. As a result, the advantages of irrigation and fertilizer will not be discussed. As a result, fertigation is the best way for applying nutrients to micro-irrigated crops (Shukla *et al*., 2018).

The nutrient distribution pattern is also influenced by the type of irrigation and fertilizer used. Leaching loss of nutrients, particularly nitrogen, can occur in surface irrigation systems where fertilizers are applied via broadcasting method due to uneven distribution of both water and nutrients. The nutrient distribution will be localized in the drip irrigation method where nutrients are applied with soil application due to the limited availability of water near the root zone. In comparison to both of the above, when fertigation is done using drip irrigation, the plant root receives a uniform distribution of water and nutrients at the same time and in the same area, resulting in increased nutrient availability and uptake (Kumar *et al*., 2016). The unequal expansion in Fertilizer consumption between states and crops, resulting in inadequate and imbalanced Fertilizer application has frequently resulted in increasing Fertilizer usage and reliance on Fertilizer imports. Furthermore, crop responsiveness to applied Fertilizer declines as a result of uneven Fertilizer application, weakening the link between Fertilizer consumption and yield potential. This also reduces the need for balanced administration of Fertilizer in water soluble form as per the crop's stage-specific requirements in the active root zone in order to achieve optimal water and fertilizer usage efficiency (NCPAH, GOI, 2017).

Benefits of Fertigation

The benefits of fertigation include healthier plants, faster delivery of nutrients to plant roots, the ability to adjust nutrient requirements with immediate effect, uniform distribution and precision application of nutrients, less labour, less water use, reduced runoff, increasing Fertilizer use efficiency and nutrient availability, saving about 20-40 percent of Fertilizer without affecting crop growth and yield, and saving labour and energy in appointing. Furthermore, fertigation reduces nitrogen losses owing to no leaching since nutrients are directly delivered to the root zone in usable forms in the form of portions.

Asa result, nutrient concentrations in soil solutions may be regulated and application costs reduced. To fertigation, all crops react. However, a lot of study has been focused on high-value crops (Solaimalai *et al*., 2005) such as potato (Badr *et al*., 2011), capsicum (Brahma *et al*., 2010; Gupta *et al.*, 2009; Srinivas and Prabhakar 1982), onion (Ewais *et al*., 2010), medicinal coleus (Kennam 2008),cucumber (Moujabber *et al*., 2002), Broccoli (Sanchita *et al*., 2010), tomato (Shedeed *et al*., 2009), pointed gourd (Singandhupe *et al*., 2007), turmeric (Syed Sadarunnisa *et al*., 2010), tomato (Tan *et al*., 2009; Tanaskovik *et al*., 2011) and some leafy vegetables (Ueta *et al*., 2009). In comparison to the traditional way of applying fertilizers, fertilization reduced fertilizer nutrients by 40% without reducing crop output (Sathya *et al.*, 2008). According to Keng *et al*. (1979), the yields from treatments with broadcast fertilizers were 15.8% less than fertigation.

Increased Fertilizer Use Efficiency

With the use of Fertigation technology scientific studies or experiments resulted that their should be higher fertilizer use efficiency for different nutrients as compare to other field practices. Table 1 supported the significant improvement in fertigation fertilizer use efficiency for main nutrients.

Increase in Yield

Fertigation ensures that nutrients are applied uniformly to the rhizosphere, where active roots are concentrated. A plant's effective foraging space (EFS) is defined as the soil region that accounts for 80%or more of root activity (Wahid, 2000). As a result, it is feasible to deliver nutrients in the EFS to ensure nearly perfect absorption based on crop requirement throughout the growing season. Furthermore, fertigation guarantees a greater and higher quality yield while saving time and labour, making fertigation economically viable (Singh, 2002). Table 2 provides an overview of the percentage production gain or increment in yield by adopting fertigation techniques in various cereal crops, fruits, vegetables and some cash crops.

Save in Water and Fertilizer

Fertigation entails not only making optimum use of the two most valuable inputs, namely water and nutrients, but also capitalizing on the synergy of their simultaneous availability to plants. Thus, fertilizer losses are avoided, and optimum absorption is ensured, because soluble nutrients are continuously supplied in tiny quantities via irrigation water. Furthermore, because the effectiveness is the best possible, the amount of fertilizer to be applied may be greatly decreased. This is due to the administration of soluble nutrients via micro irrigation system solely to the wetted root zone. Easy and consistent application in

Table 1 : Fertilizer use efficiency in Fertigation (%).

Nutrient	Fertilizer Use Efficiency (%)		
	Surface irrigation + Soil application of Fertilizer	Drip	Drip fertigation
Nitrogen	30-50	65	95
Phosphorus	20	30	45
Potassium	50	60	80

Fertilizer Marketing News, 2010

Table 2 : Increase in Yield through Fertigation.

Name of the Crops	Increase in Yield (%)	Reference
Cereals		
Rice	11.7	Suvarna *etal*. (2021)
Maize	8.5	Suvarna *etal*. (2021)
Vegetables		
Chilli	24.7	Veeranna *et al*. (2001)
Capsicum	15.1	Sandal *et al*. (2015)
Cauliflower	21.3	Sandal *et al*. (2015)
Tomato	19.9	Hebbar *et al*. (2004)
Brocolli	21.4	Sandal *et al*. (2015)
Sweet Pepper	7-25	Kaushal *et al*. (2012)
Brinjal	15.4	Sandal *et al*. (2015)
Onion	41	Rumpel *et al*. (2004)
Potato	11.5	Suvarna *et al*. (2021)
Beet root	54	Shah (2011)
Fruits		
Citrus	22.05	Barua, (2013)
Grape	30	Brahmanand and Singandhupe (2001)
Pomegranate	30	Brahmanand and Singandhupe (2001)
Guava	25	Brahmanand and Singandhupe (2001)
Custard Apple	20	Brahmanand and Singandhupe (2001)
Cash Crops		
Cotton	10.3	Suvarna *et al*. (2021)
Sugarcane	11	Suvarna *et al*. (2021)

Table 3 : Save in Fertilizer through Fertigation.

Name of the Crops	Save in Fertilizer (%)	Reference
Vegetables		
Chilli	20	Veeranna *et al*. (2001)
Sweet Pepper	20-33	Kaushal *et al*. (2012)
Okra	30-50	Rekha and Mahavishnan (2008)
Cucumber	20	Gupta *et al*. (2014)
Onion	25	Bhakare and Fatkal (2008)
Cash Crop		
Cotton	25	Bhakare *et al*. (2015)

Table 4 : Save in Water through Fertigation.

Name of the Crops	Save in Water (%)	Reference
Vegetables		
Okra	40-70	Rekha and Mahavishnan (2008)
Onion	39	Kaushal *et al*. (2012)
Cucumber	37.8	Gupta *et al*. (2014)
Sweet Pepper	20-60	Kaushal *et al*. (2012)
Beet root	79	Shah (2011)
Pulses		
Mungbean	28-50	Jat *et al*., 2019
Chickpea	15-24	Sawargaonkar *et al*. (2013)
Cash Crops		
Cotton	24-48	Thind *et al*. (2008) and Pendergast *et al*. (2013)
Sugarcane	28-46	Oliveira *et al*. (2014) and Singh *et al*. (2020)
Fruit Crops		
Grape	65-70	Brahmanand and Singandhupe (2001)
Pomegranate	50-55	Brahmanand and Singandhupe (2001)
Guava	55-60	Brahmanand and Singandhupe (2001)
Custard Apple	50-55	Brahmanand and Singandhupe (2001)

influenced by water (Rom and Kaushal, 2014). Crops may produce large yields and have efficient growth rates if irrigation techniques are used properly.

Fertigation (the injection of fertilizer solution into the soil) efficiently minimizes surface runoff, evaporation between plants, and deep percolation when compared to ordinary furrow irrigation methods (Cai *et al*., 2002). Here, Tables 3 and 4 indicates the Fertilizers saving and water savings in percentage respectively achieved by fertigation in various crops. Whereas, Table 5 indicates result of different drip fertigation techniques over Grain yield, water and nutrient savage compared to farmers practices in cereal crops.

Basic Guidelines for Fertigation

The following are some fundamental guidelines for fertigation (Burt, 1998);

i) About 50–75% of the water needed to combine dry and soluble Fertilizers should be added to the mixing tank (container).

ii) In the mixing container, put the liquid Fertilizers first, followed by the dry and soluble Fertilizers. If the dry Fertilizers have the tendency to make solutions cool, the extra fluid will generate some heat.

iii) To avoid the development of significant, insoluble, or slowly dissolving lumps, add the dry elements gradually while dispersing or shaking.

iv) Put acid into water rather than water into acid.

v) Chlorine is added to water when it is chlorinated with chlorine gas.

Table 5 : The impact of surface drip fertigation (SDF) and sub-surface drip fertigation (SSDF)techniques on Grain yield, Water and Nitrogen savings compared to farmer's practices (FP) in Cereal Crops (Kakraliya *et al*., 2021)

Crops	Method of fertigation	Grain Yield (t ha^{-1})	Save in water (%)	Save in N fertilizer (kg ha^{-1})	References
Rice	SDF	+/- 0.36	10-25	15	Sidhu *et al*. (2019)
	SSDF	0.16-0.53	20-40	15-45	Sidhu *et al*. (2019) and Jat *et al*. (2019)
Wheat	SDF	0.29-0.53	18-30	0	Sidhu *et al*. (2019) and Sandhu *et al*. (2019)
	SSDF	0.33-1.11	22-47	25	Sidhu *et al*. (2019) and Jat *el al*. (2019)
Maize	SDF	0.55-1.07	25-30	0	Sandhu *et al*. (2019)
	SSDF	0.23-0.54	30-45	35	Jat *et al*. (2019)

soluble form via irrigation water ensures labour cost savings, particularly for topdressing. The ideal crop production under fertigation was frequently achieved at 50% of the locally suggested N rate under traditional irrigation, resulting in significant savings of expensive fertilizer N while also lowering the potential pollution threat. Crop productivity and quality are significantly

vi) Never combine chlorine with an acid or an acidified Fertilizer, whether the chlorine is in gas or liquid form (such as sodium hypochlorite). The chlorine gas will become poisonous. Never keep chlorine and acids in the same space.

vii) Avoid attempting to combine any type of acid directly

Table 6 : Response of Fertigation on Major Fruit, Vegetable and Plantation crops (Jeyabaskaran *et al*., 2021).

S. no.	Crop	Crop Response	Reference
		Fruit Crops	
1.	Mango cv. Dashehari	Increase in growth yield and quality, in addition to soil fertility	Panwar *et al*. (2007)
2.	Mango cv. Alphonso	Increase in fruit yield and quality	Prakash *et al.* (2015)
3.	Mango cv. Dashehari	Improvement in nutrition distribution, nutrient use efficiency coupled with better soil moisture distribution and yield	Adak *et al.* (2014)
4.	Guava cv. Shweta	Increase in flowering, leaf nutrient status, growth, yield and quality	Ramniwas *et al*. (2013)
5.	Guava cv. Shweta	Increase in growth and fruit yield	Sharma *et al.* (2013)
6.	Pomegranate cv.Bhagwa	Good fruit yield and quality	Haneef *et al.* (2014)
7.	Pomegranate cv. Mridula	Improves flowering	Shanmugasundaram *et al*. (2013)
8.	Almond cv. Waris	Increase in growth response and yield	Dinesh Kumar and Almed (2014)
9.	Banana cv. Robusta	Increase in uptake of nutrients	Senthilkumar *et al.* (2014)
10.	Banana cv. Robusta	Improves growth, yield and quality	Mahendran *et al.* (2013)
11.	Apple cv. Gala on M-26 rootstock	Improves root distribution	Neilsen *et al.* (2000)
12.	Apple cv. Gala on M-9 rootstock	Improves growth and yield initially with N-fertigation	Treder (2006)
13.	Strawberry cv. Chandler	Improves growth, yield and quality	Kachwaya and Chandel (2015)
14.	Papaya cv. Taiwan	Improves growth, yield and quality	Deshmukh and Hardha (2014)
15.	Acid lime cv. Kagzi lime	Improves growth, yield and quality and leaf nutrient composition	Shirgure*et al.* (2014)
16.	Nagpur mandarin	Improves growth, yield and quality and leaf nutrient composition and soil fertility	Shirgure *et al.* (2016)
17.	Watermelon	Improves plant height, number of leaves, fruit weight and increases yield	Sabo *et al.* (2013)
		Vegetable crops	
18.	Tomato	Fertigation helps in higher uptake of NPK, higher leaf area index, root growth and improves fruit yield	Kalanjiyam and Manickam (2015)
19.	Potato	Improves the tuber potato quality	Mohamed *et al*. (2014)
20.	Cabbage	Increases head diameter, TSS and ascorbic acid content	Vasu and Reddy (2013)
21.	Chilli	Increases number of leaves, plant height and yield	Chaurasiya and Sahu (2016)
22.	Curry leaf	Improves plant growth, increases secondary branches and leaves	Rajaraman and Paramaguru (2011)
23.	Corriander	Improves growth and quality	Sharon *et al.* (2012)
24.	Cauliflower	Increases yield	Bozkurt *et al.* (2011)
25.	Spinach	Increases nitrogen, WUE and growth	Zhang *et al.* (2014)
26.	Brinjal	Improves total uptake of NPK, Maximum fertilizer use efficiency	Ugade *et al.* (2013)

Table 6 continued...

Table 6 continued...

27.	Onion seed crop	Increases seed per umbel, seed yield per umbel per plant	Dingre *et al.* (2016)
		Plantation Crops	
28.	Cocoa	Increase in growth parameters such as trunk girth, canopy spread and weight of pruned branches removed, fresh and dry weight of leaves	Krishanamoorthy*et al.* (2013)
29.	Arecanut	Increase in leaf water potential, root biomass and organic carbon content in soil and significantly increase in water use efficiency and agronomic nutrient use efficiency	Bhat *et al.* (2007)

Table 7 : Fertilizers appropriate for fertigation.

Nutrients	**Fertilizers**	**% Nutrient**
N	Urea Ammonium sulphate Urea ammonium nitrate (L) Ammonium nitrate	46% N 21% N 32% N 34 % N
N and P	Mono ammonium phosphate Urea Phosphate	12% N, 61% P_2O_5 17% N, 44% P_2O_5
P	Phosphoric acid	52% P_2O_5
P and K	Mono potassium phosphate	52% P_2O_5, 34% K_2O
K	Potassium chloride Sulphate of Potash Potassium nitrate (Multi K) Potassium thiosulphate	60% K_2O 50% K_2O, 17.5% S 13% N, 46% K_2O 25% K_2O, 17.5% S
N, P and K	Poly feed Urea Phosphate with SOP	19-19-19 % NPK 18-18-18 % NPK
Mg and Ca	Magnesium nitrate Calcium nitrate	11% N 16% N, 19% Ca

with either anhydrous ammonia or aqua ammonia. The response comes quickly and violently.

viii) Direct mixing of concentrated Fertilizer solutions with other concentrated fertilizer solutions is not recommended.

ix) Sulfate-containing substances should not be used with calcium-containing substances. A combination of gypsum that is insoluble will be the outcome.

x) For information on insolubility and compatibility, always verify with the chemical source.

xi) Mixing urea sulfuric Fertilizers with the majority of other substances should be done with utmost caution. Numerous substances are incompatible with urea sulfuric.

xii) If chemicals are spoon-fed, many compatibility issues have a tendency to go away.

xiii) Never combine calcium-containing Fertilizers with phosphorus-containing fertilizers without first doing the jar test.

xiv) Extremely hard water, which has high concentrations of calcium and magnesium, will generate insoluble materials when it reacts with phosphate, neutral polyphosphate, or sulphate compounds.

Fertigation Apparatus (Shukla *et al.*, 2018)

Incorporating Fertilizers into irrigation systems requires the following fundamental requirements:

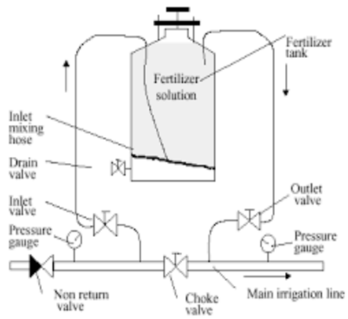
A. Fertilizer Injection Equipment

Choosing the right injection equipment is equally crucial as selecting the right nutrients. Injecting Fertilizer solution requires a higher pressure than internal pressure. A filter is necessary to prevent solid Fertilizer particles from entering the dripper and clogging it. A back-flow prevention valve is necessary to avoid chemical backflow into the water supply. Fertilizer injectors are the most critical components of the fertigation system. There are three types of injectors, as follows:

Pressure differential (Bypass tank) (Fig. 1)

This system relies on a pressure difference generated by valves and pressure management. Water enters a pressure tank containing Fertilizer through a bypass pipe and exits with variable amounts of dissolved Fertilizer. Nutrient application is quantitative and imprecise, making it best suited for perennial crops like citrus and fruit trees.

a) Fertilizer tank



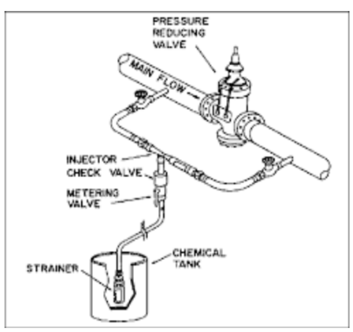
b) Working of Fertilizer tank

Fig. 1 :

Vacuum injection (Venturi) (Fig. 2)

This is based on the Venturi tube idea. A pressure differential between the injector's intake and output creates a vacuum, drawing the Fertilizer solution into the line.

a) Venturi



b) Working of Venturi

Fig. 2 :

Pump injection (Fig. 3)

Pumps are used to transfer Fertilizer solution from a supply tank to the line. Electric or hydraulic motors power the injection process.

a) Pump injection

Fig. 3 :

B. Fertilizers

Fertilizers are the second essential element for fertigation. When choosing fertilizers for fertigation, it's important to consider two factors:

i) the solubility of the fertilizer in the water source, as irrigation water may contain chemical constituents that can interact with dissolved fertilizers and

ii) the acidity of the fertilizer solution, which can corrode irrigation system components.

Fertilization mostly uses nitrogen and potassium-based fertilizers. Phosphorus and micro-nutrient formulations can be utilized with irrigation water that has a pH below 6.5. To prevent precipitation difficulties, avoid mixing P fertilizers with calcium nitrate and iron.

Fertilizer characteristics for fertigation

- Plants can easily access nutrient-rich soil.
- Minimum amount of conditioning agents.
- Fully soluble at field temperatures.
- Compatible with different Fertilizers.
- Quick dissolving in irrigation water.
- Minimal contact with irrigation water.
- No clogging of filters or emitters.
- No significant changes to water pH.
- Low insoluble content (<0.02%).
- The control head and system contain low levels of corrosion.

Conclusion

A fertilization system is a productive way to apply fertilizers, using the irrigation system to transport and distribute the crop's nutrients. The crop plants utilize both nutrients and water effectively asa result of the combination of the two. One of the best methods for applying water and nutrients has been discovered to be fertilization. Fertigation not only boosts economic yields but also promotes optimal fertilizer nutrient usage, reduces labour costs and boosts productivity. Agro-climatic conditions and a wide variety of crops have all reported yield gains. Due to their broad spacing requirements, constant need for water and nutrients at an ideal rate to offer large yields with good quality and high capital returns on the investments, fruit and vegetable crops have been proven to be responsive to fertigation.

Although, the initial cost to set up the fertigation system is expensive, over the long run it is more cost-effective than traditional methods of fertilization since it lowers the cost of cultivation. However, in order to get the required outcomes, greater management skills at the operator level are needed for things like fertilizer selection, timing and rate of fertilizer injection, watering schedules and system maintenance.

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