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Review article

Citrus fertigation – a technology of water and fertilizers saving

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ABSTRACT

Fertigation is the application of soluble fertilizers through micro-irrigation systems, has been used in citrus production since the 1960s. Originally, fertigation was used in arid regions to improve solubility of fertilizers in the root zone and increase uptake efficiently by fruit trees. Without rainfall or irrigation, dry fertilizers often remained on the soil surface and nutrients were lost due to leaching or volatilization. Currently fertigation is being used in many citrus growing regions including Israel, the Mediterranean region, South Africa, and the United States. Nevertheless, many regions in our country still use dry fertilizers due to tradition, lack of fertigation equipment, technique, uneven topography or poor quality irrigation water. The objective of this popular article is to discuss fertigation, advantages and disadvantages of fertigation, methods of fertigation, fertigation in citrus production based on research and observations from citrus growing regions in India.

1. Introduction

Fertigation is the application of soluble fertilizers through micro-irrigation systems, has been used in citrus production since the 1960s. Originally, fertigation was used in arid regions to improve solubility of fertilizers in the root zone and increase uptake efficiently by fruit trees. Without rainfall or irrigation, dry fertilizers often remained on the soil surface and nutrients were lost due to leaching or volatilization. Currently fertigation is being used in many citrus growing regions including Israel, the Mediterranean region, South Africa, and the United States. Nevertheless, many regions in our country still use dry fertilizers due to tradition, lack of fertigation equipment, technique, uneven topography or poor quality irrigation water. The objective of this popular article is to discuss fertigation, advantages and disadvantages of fertigation, methods of fertigation, fertigation in citrus production based on research and observations from citrus growing regions in India.

2. Advantages of citrus fertigation

There are several advantages of using fertigation over conventional dry application of fertilizers. Nutrients are already in soluble form when applied and are thus potentially more available for uptake by the tree than dry materials. Moreover, the soil concentration of nutrients can be maintained within specific ranges throughout the year. Some citriculturists also believe that tree growth and yields are improved if nutrients are applied in small amounts but continuously over infrequent heavy applications. In addition, nutrients can be placed directly in the root zone, which especially useful for young trees, by adjusting the type of irrigation emitter used. In arid and semiarid regions roots are concentrated near emitters that are the source of water, thus nutrient uptake is very efficient. Concentrating nutrients in the root zone also reduces losses due to leaching and in arid regions; limits weed growth primarily to wetted regions. In humid regions with high rainfall, roots are more widely distributed over the orchard floor and the root concentrating effect of fertigation is less pronounced.

Fertigation systems are easily automated and provide an effective delivery system for water and fertilizer. Once the tanks, injectors and back flow valves have been purchased and the irrigation is in place, many citrus trees can be fertigated at the touch of a switch. A wide range of application frequencies are available, ranging from daily to monthly, and can be adjusted easily without additional costs for fertilizer spreaders or labor. A properly maintained and managed fertigation system in addition is an effective means of irrigating. Thus, citrus tree water relations are also often improved when using fertigation.

3. Disadvantages of citrus fertigation

Fertigation may not be the method of choice for all citrus growers. Costs are associated with the purchase and maintenance of tanks, injectors, back flow valves, timers and other equipment necessary to fertigate trees. Citrus growers with small plantings may not be able to justify such costs. The irrigation system must be balanced to provide the same amount of water and nutrients to each tree. Poorly designed systems may lead to tree losses or unequal growth. Furthermore, irrigation laterals and emitters must be kept clean and functional which requires intense management. Where citrus trees are grown in mountainous regions, the topography limits the efficiency and cost effectiveness of micro irrigation, and consequently fertigation becomes impractical.

Water quality is an important concern when fertigating citrus trees. Water with high pH, magnesium and calcium levels may cause precipitation of phosphorus from the fertilizer. Water high in salts may not be suitable for fertigation since some nitrogen source such as ammonium nitrate or potassium chloride increase total dissolved solids in the irrigation water and may cause damage to trees (Alva and Syversten, 1991). Citrus trees, particularly those on trifoliate or trifoliate-hybrid rootstocks, are salt sensitive. Therefore, water quality should be tested before using fertigation and monitored after fertilizer is injected into the system. Liquid fertilizers also may crystallize causing precipitates to form in the tank at temperatures below 15ºC (Obreza et al., 1992). A partial solution to this problem is to use lower analysis fertilizers that salt-out at lower temperatures. For example, a 1O(N) : O(P) : 1O(K) analysis fertilizer crystallizes at 15ºC; whereas, a 6(N) : O(P) : 6(K) analysis material crystallizes at -3ºC. Use of potassium chloride vs. potassium nitrate in the fertilizer formulation also reduces salting-out at low temperatures.

4. Fertilizer injection (fertigation) methods

It is important to select an injection method that best suits the irrigation system and the crop to be grown. Incorrect selection of the equipment can damage parts of the irrigation equipment, affect the efficient Operation of the irrigation system and reduce the efficiency of the nutrients. Each fertilizer injector is designed for a specified pressure and flow range.The majority of injectors available today can generally incorporate automatic operation by fitting pulse transmitters that convert Injector pulses into electric signals. These signals then control injection of preset quantities or proportions relative to flow rate of the irrigation system Injection rates can also be controlled by flow regulators, chemically resistant ball valves or by electronic or hydraulic control units and computers.

Suitable antisiphoning valves or non-return valves should be installed to prevent backflow or siphoning of water and fertilizer solution into fertilizer tanks, irrigation supply and household supply. The modern fertigation equipment should be able to regulate,

- Fertilizer quantity applied
- Fertigation duration of application
- Ratio of different proportion of fertilizers
- Starting and finishing time

The main fertigation methods are,

A. Pressure differential (by-pass tank)
B. Vacuum injection (Venturi) and
C. Pump injection

A. Pressure differential (by-pass tank)

A pressure differential tank system is based on the principle of a pressure differential created by a valve, pressure regulation, elbows or pipe friction in the mainline (Fig.1). The pressure difference forces the water to enter through a by-pass pipe into a pressure tank which contains the fertilizer, and to go out again, carrying a varying amount of dissolved fertilizer. The application of nutrients is quantitative and inaccurate, therefore is adapted for perennial crops like citrus, fruit trees and/or crops grown on heavy soil.

Advantages:

- Very simple to operate, the stock solution does have not to be pre-mixed
- Easy to install and requires very little maintenance
- Easy to change fertilizers
- Ideal for dry formulations
- No electricity or fuel is needed

Disadvantages:

- Concentration of solution decreases as fertilizer dissolves
- Accuracy of application is limited
- Requires pressure loss in main irrigation line or a booster pump
- Proportional fertigation is not possible
- Limited capacity
- Not adapted for automation
- Inlet valve

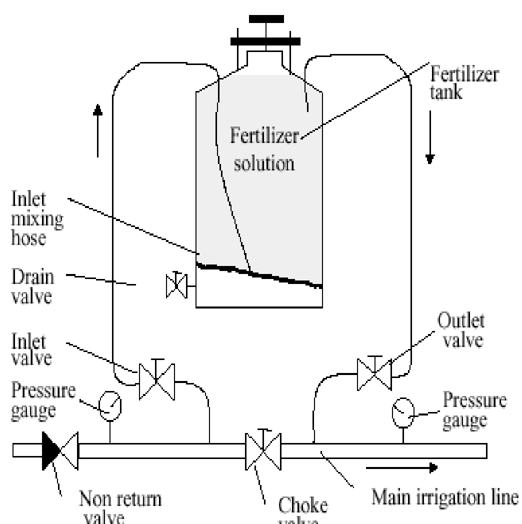

Fig. 1. Fertigation with fertilizer tank.

B. Vacuum injection (Venturi)

This method uses a venturi device to cause a reduced pressure (vacuum) that sucks the fertilizer solution into the line (Fig.2).

Advantages:

- Very simple to operate, no moving parts
- Easy to install and to maintain
- Suitable for very low injection rates
- Injection can be controlled with a metering valve
- Suitable for both proportional and quantitative fertilization

Disadvantages:

- Requires pressure loss in main irrigation line or a booster pump
- Quantitative fertigation is difficult Automation is difficult.
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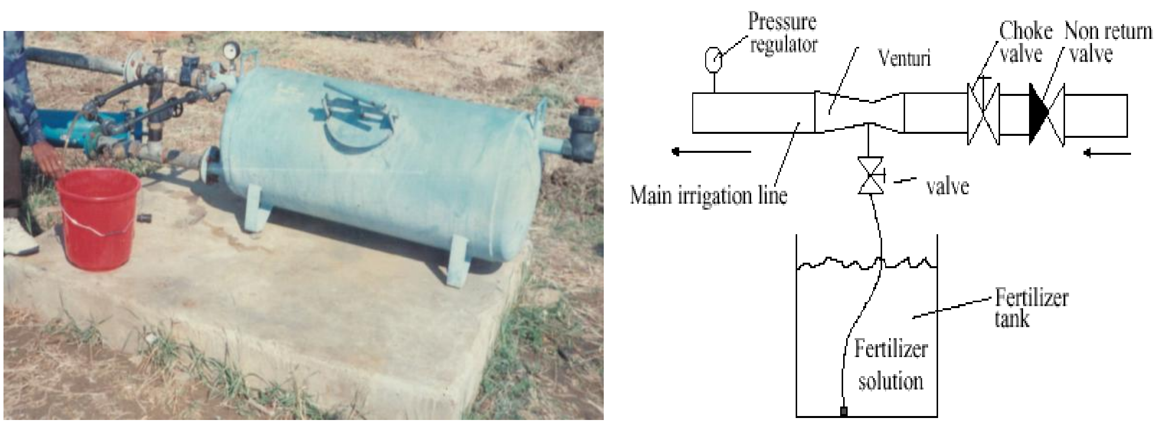

Fig. 2. Fertigation with venture.

C. Pump injection (liquid dispenser)

Pumps are used to inject the fertilizer solution from a supply tank into the line. Injection energy is provided by electric motors, hydraulic motors (diaphragm and piston) (Fig.3).

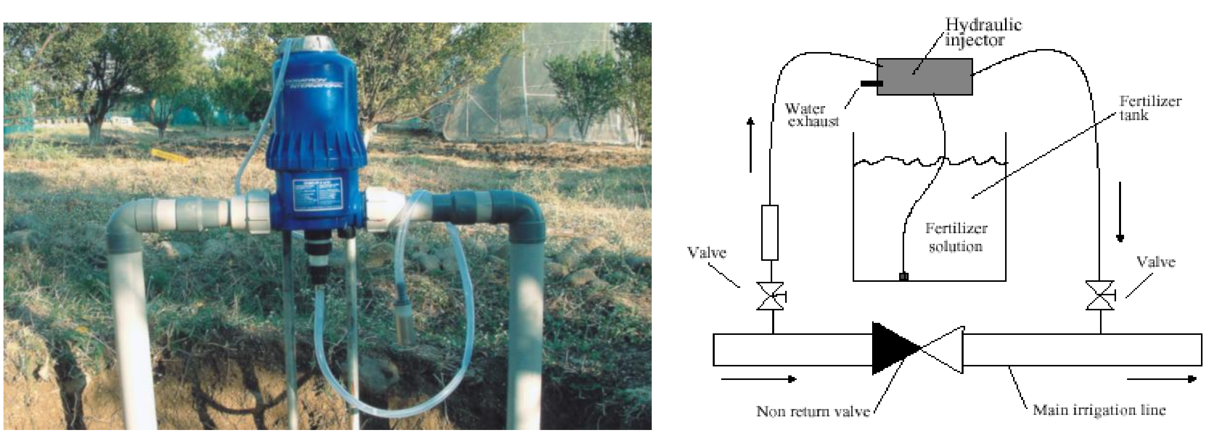

Fig. 3. Fertigation with injection pump.

Advantages:

Very accurate, for proportional fertigation
No pressure loss in the line
Easily adapted for automation

Disadvantages:

Expensive
Complicated design, including a number of moving parts, so wear and breakdown are more likely

4. Fertilizers of the fertigation

Nitrogen fertilisers : Plants absorb and use most of the nitrogen as nitrate or ammonium ions.
The main types of nitrogen are:

- Nitrate - ammonium nitrate
- Ammonium - sulfate of ammonia
- Amide - urea
- Combination of nitrate and amide - Easy N®
- Brand name products as straights or compounds.

Urea is commonly used and preferred because:

- It is most concentrated and usually the best price per kilogram of nutrient
- It does not leach readily
- It dissolves readily, converting to ammonium carbonate (alkaline) then nitrate.

Compared with ammonium nitrogen, which can be held on clay and organic particles, and with nitrate, which moves freely and can be leached quickly, moving to the perimeter of the wetted zone in the soil, urea offers the best value. In colder soil conditions during winter, nitrate forms of nitrogen are preferred.

5. Phosphorus fertilizers

Phosphorus supply is usually provided by:

- Phosphoric acid
- MAP (mono-ammonium phosphate)
- DAP (di-ammonium phosphate)
- Brand name liquids.

The possibility of precipitation of insoluble phosphates is high when using MAP or DAP with irrigation water that is high in calcium or magnesium. This will cause clogging of outlets and pipelines. Phosphoric acid provides the advantage of cleansing lines and sprays and is a concentrated liquid offering ease of use. Providing the pH of the water is kept low, clogging or precipitation should not be a problem. This can be done by using more acid. Phosphoric acid must be injected at a point beyond any metal connections or filters in order to avoid corrosion. If using MAP or DAP be aware that these fertilisers do not dissolve completely so your mixing tank will need facilities for cleaning out the undissolved residue which collects at the bottom of the tank. MAP or DAP, although not as soluble as phosphoric acid, have the added bonus of also supplying nitrogen.

One litre of phosphoric acid (this contains 60% H3PO4) weighs 1.55 kg and is equal to 20% P (actual) and therefore equals 0.31 kg of P/litre. Single super equals 9% P, so 1 kg = 0.09 kg of P.

Therefore, one litre of phosphoric acid is equivalent to:

- 3.44 kg of single super, or
- 1.94 kg of double super, or
- 1.68 kg of trifos.

6. Potassium fertilizers

Irrigators can choose from:

- potassium nitrate
- potassium sulfate
- potassium chloride
- brand name mixed fertilisers and liquids.

Potassium nitrate is the recommended source of potassium for use in fertigation programs because of its solubility and added bonus of providing nitrogen. It is, however, the most expensive of the potassium fertilisers. Potassium sulfate is inferior to the other two sources as its solubility is not as high. Potassium chloride is the most economic of the potassium fertilisers, but can be a problem with crops that are sensitive to high chlorine concentrations such as stone fruit, pecans, citrus, strawberries and avocados. For these crops a mixture of potassium sulfate and potassium chloride can be used to reduce costs.

7. Other macronutrients

Soluble forms of the three lesser macronutrients - calcium, magnesium and sulfur - do exist but these are much more expensive, not always compatible with mixes and can cause precipitation and clogging. The conventional forms of these nutrients - lime, gypsum and dolomite - should be spread in the normal way.

8. Micronutrients

Chelates and sulfate compounds of various micronutrients are generally used for correcting micronutrient deficiencies. These compounds should be predissolved and metered into your tank as a liquid.

The micronutrients that can be supplied via your irrigation system include: copper, iron, zinc, manganese, boron and molybdenum.

What are the systems of fertigation ?

Modern fertigation should be able to regulate:

- quantity applied
- duration of applications
- proportion of fertilisers
- starting and finishing time.

Four systems are generally used:

1. Continuous application. Fertiliser is applied at a constant rate from irrigation start to finish. The total amount is injected regardless of water discharge rate.
2. Three-stage application. Irrigation starts without fertilisers. Injection begins when the ground is wet. Injection cuts out before the irrigation cycle is completed. Remainder of the irrigation cycle allows the fertiliser to be flushed out of the system.
3. Proportional application. The injection rate is proportional to the water discharge rate, e.g. one litre of solution to 1000 litres of irrigation water. This method has the advantage of being extremely simple and allows for increased fertigation during periods of high water demand when most nutrients are required.
4. Quantitative application. Nutrient solution is applied in a calculated amount to each irrigation block, e.g. 20 litres to block A, 40 litres to block B. This method is suited to automation and allows the placement of the nutrients to be accurately controlled.

9. Fertigation management

The effectiveness of fertigation is often dependent on the effectiveness of the irrigation system. The full advantages of irrigation and fertigation only become evident if the correct irrigation design is employed to meet plant requirements and to distribute water and fertiliser evenly. Because of the corrosive nature of many fertilisers, the components of the irrigation system that come into contact with corrosive solutions should consist of stainless steel, plastic or other non-corrosive materials. Concentrations of total nutrients in the mainline should not exceed 5 grams/litre. Always mix fertilisers in sufficient volume of water. The following formula can be used to determine the injection rate:

Maximum injection rate = (5 × Q × L) ÷ (F × 60)

where:

Q = irrigation pump discharge in litres per second

L = fertiliser tank volume in litres

F = amount of fertiliser in grams

For each crop there are many fertiliser programs. Fertigation allows you to change your program during the growing season, adjusting it to suit fruit, flower, shoot and root development. A program should be developed on the basis of leaf and soil analysis and tailored to suit your actual crop requirements. The majority of injectors available today can generally incorporate automatic operation by fitting pulse transmitters which convert injector pulses into electric signals. These signals then control injection of preset quantities or proportions relative to flow rate of the irrigation system. Injection rates can also be controlled by flow regulators, chemically resistant ball valves or by electronic or hydraulic control units and computers.

If fertilisers are not completely dissolved and mixed prior to injection into the system, this may result in varying concentrations applied or blockages within the system. Suitable antisiphoning valves or non-return valves should be installed where necessary to prevent backflow or siphoning of water, fertiliser solution, chemical solution etc. into fertiliser tanks, irrigation supply, household supply, stock supply and so on.

10. Fertigation system hygeine

Fertigation increases the quantity of nutrients present in an irrigation system and this can lead to increased bacteria, algae and slime in the system. These should be removed at regular intervals by injection of chlorine or acid through the system. Chlorine injection should not be used while fertiliser is being injected into the system as the chlorine may tie up these nutrients making them unavailable to the plant. Systems should always be flushed of nutrients before completion of irrigation. Before commencing a fertigation program, check fertiliser compatibilities and solubility.

During the irrigation season it is important to monitor:

- pH effects over time in the root zone
- soil temperature effect on nutrient availability
- corrosion and blockages of outlets
- reaction with salts in the soil or water.

11. Responses of citrus trees to fertigation

The influence of fertigation on growth, yields and fruit quality of citrus trees has been studied for more than 30 years, with differing, sometimes contradictory findings. Results differ based on climate, soil type, root distribution and possibly tree age. Fertigation is an effective method of fertilizing in arid climates such as Israel (Dasberg et al., 1983). Fertilizer levels in the soil are maintained at constant levels of 35-60 mg/kg throughout the irrigation period. Studies suggest that optimum nitrogen rate for mature Shamouti orange trees is about 170 kg/ha/year. Higher nitrogen (N) rates increased yields but decreased external fruit quality by delaying peel color development and increasing peel thickness. However, juice quality, specifically total soluble solids, was not affected by nitrogen rate. The reduction in fresh fruit quality and increased costs for the additional nitrogen are probably not economically warranted. Similarly, research from Spain with navel oranges showed that daily fertigation significantly increased yields over application of dry fertilizer twice/year (Legaz et al., 1981). Optimum nitrogen rate was 0.75 kg/tree/yr. High N rates increased fruit weight and number but also increased peel thickness and decreased juice content. In this instance, fertilizer was applied using 8 drippers / tree to insure adequate root zone coverage that is an important factor in any fertigation program.

Fertigation does not always increase tree growth and yields over application of dry materials. Therefore, general recommendations concerning its effects cannot be made. Studies from South Africa found no difference in growth of young Valencia orange trees during the first 4 years after planting when using fertigation (6 times per year) vs. dry application (4 times per year) at the same nitrogen rates (Bester et al., 1977). Fertigation effects on tree performance are even less pronounced in humid subtropical areas such as Florida and Texas. In contrast to Spanish and Israeli findings, growth of 1-2 year old ´Hamlin´ orange trees was similar for fertigated and dry applications over a range of nitrogen rates (Willis et al., 1990). Moreover, increasing frequency of applications from 5 to 30 times per year (weekly) had no effect on growth. Nevertheless, soil-nitrate nitrogen levels and the potential for nitrate pollution of groundwater were reduced significantly by frequent fertigation over less frequent dry fertilizer application. Research on mature orange and grapefruit trees in Florida also showed no yield increases for fertigated vs. non-fertigated (dry application) trees (Koo, 1980). However, fertigation decreased juice acidity. In addition, ´Ruby Red´grapefruit trees in Texas grew and yielded similarly for the first 4 years after planting whether they received dry or liquid fertilizer (Swietlik, 1992). In contrast to the above, fertigation using reclaimed wastewater increased yields over dry application for mature grapefruit trees on the east coast of Florida (Maurer et al., 1995). In this instance, reclaimed wastewater containing less than 10 ppm nitrates, was applied twice /week or more than 100 times/year. Increased yields may also have occurred due to improved water relations, although soil water content was maintained in the optimum range for all treatments.

Climate is likely the most important determinate of improved tree performance related to fertigation. Specifically, rainfall amount and seasonal distribution affects root distribution. In arid or semiarid regions roots are concentrated around irrigation emitters allowing concentration of nutrients in the root zone. In areas with high rainfall, roots are naturally more widely distributed and consequently fertigation of a portion of the root zone does not improve tree growth or yields. Adequate coverage (60-70%) of the root zone using drippers or micro sprinklers is also likely related to effectiveness of fertigation. Coverage patterns are related to soil texture and irrigation emitter type. Micro sprinklers typically cover more area than drippers, particularly in well drained sandy soils, although trickle irrigation is effective in heavy soils if multiple drippers are used or under tree different degree micro-jets of 1800 or 3000 (2/plants) are found suitable under central Indian conditions, where the soil is black cotton (shirgure et al., 2003b).

12. Application rates, frequencies and fertilizer sources

Nitrogen application rates for fertigated mature, bearing trees range from 150 to 200 kg/ha/yr. for most citrus growing regions worldwide. Major sources of nitrogen include ammonium nitrate and sulfate, urea and potassium nitrate. Phosphorus and potassium rates vary with growing region and previous fertilization practices and should be based on leaf and soil analyses. Therefore, generalizations concerning phosphorus and potassium rates cannot be made. Major sources of phosphorus include phosphoric acid and polyphosphate; potassium sources include potassium nitrate and potassium chloride. Choice of fertilizer source depends on pH, calcium, magnesium and total dissolved solids levels in the irrigation water. Application frequency ranges from daily to weekly to biweekly depending on growing region and management preference. The consensus is that frequent application is preferred because it may increase tree growth and yields and decrease nutrient losses due to leaching.

The investigations was carried out on three years old Acid lime (Citrus aurantifolia Swingle) during 1995-97 to see the effect of nitrogen fertigation using Urea through drip irrigation on leaf nitrogen and fruit quality. Fertigation with 60%, 80% and 100% N of the recommended doses were compared to the Band placement (100% N) method of fertilizer application. The plants were fertigated at monthly interval from October to June and in Band placement fertilizers were applied during October, February and June. The differential nitrogen dose was given using Urea and Phosphorus and Potash was given at constant doses. During no-rainy period the plants were irrigated using drip irrigation system. The leaf samples of the Ambia flush was taken during 1995 and 1997. These samples were analysed for N, P and K uptake due to nitrogen fertigation (Shirgure et al., 1999). The percentage increase in plant height, plant girth and canopy volume was maximum with 100 % N fertigation followed by with 80 % N fertigation. The percentage increase in plant height, plant girth and canopy volume was better in band placement treatment as compared to 60 % N fertigation treatment. The percentage increase in leaf Nitrogen content was more in case of 80 % N fertigation (27.47 %) followed by 100 % N fertigation (24.32 %) , 60 % N fertigation (20.23 %) and band placement (7.5 %). This study clearly indicates the advantage of N fertigation over the conventional method of fertilizer application. The leaf Nitrogen was 2.32%, 2.3% and 2.02% in 100%, 80% and 60% N fertigation treatments respectively. The leaf nitrogen was only 2.0% in Band placement method of fertilizer application. The uptake of Phosphorus and Potash was also more in 100% N fertigation. The fruit weight (34.4 gm), diameter (39.4 mm) and height (40.2 mm) was more in 100% N fertigated plants. The TSS, (7.08), juice percentage (49.0%) and acidity (4.1%) was more in 80% N fertigation. The TSS to acidity ratio was low (1.46) in 80% N fertigation. The study clearly indicates the advantage of N fertigation over the conventional fertilizer application method (Shirgure et al., 2001c).

A field experiment was also conducted on Nagpur mandarin (C. reticulata) during 1998-2000 at NRC for Citrus, Nagpur. The treatments were 4 levels of irrigation (10 %, 20 %, 30 % and 40 % depletion of available water content) and 3 levels of fertigation (600, 200 and 100 g; 500, 140 and 70 g and 400, 80 and 40 g N, P and K /plant). The incremental plant height (0.46 m), girth (19.9 cm) and canopy volume (14.3 m3) was more with irrigation scheduled at 20 % depletion of available water and 500, 140 and 70 g N, P and K /plant fertigation. The fruit yield (26.1 kg/ tree), fruit weight (135.1 g), total soluble solids in fruits and juice percentage (47.32 %) were higher with irrigation scheduled at 20 % and 500, 140 and 70 g N, P and K /plant fertigation (Shirgure et al., 2001a). The incremental height, stock girth and canopy volume of bearing acid lime was more in irrigation scheduled at 30 % depletion of available water content with 500:140:70 fertigation. The combined effect of irrigation at 30 % depletion of available water content and fertigation with 500:140:70 gave better growth and yield of acid lime. The average fruit yield was 15.83 kg/ tree in 30 % depletion of available water content. The average fruit weight and total soluble solids was 30.1 g and 8.1 % in irrigation scheduled at 30 % depletion of available water content with 500 : 140 : 70 fertigation. The juice percent and acidity with irrigation scheduled at 30 % depletion of available water content and 500:140:70 fertigation was more (42.5% and 7.0%) as compared to other treatments (Shirgure et al., 2003a, Shirgure et al., 2004).

The bearing Nagpur mandarin was fertigated during 2003-2005 to evaluate the effects of different potash fertilizers applied through drip irrigation system during different seasons on yield and quality behaviors of 14 years Nagpur mandarin. Among the nutrients that the orange tree requires is potassium which, when applied in different amounts can affect the yield and quality of fruit. The treatment consisted of fertigation with potassium chloride, potassium nitrate sulphate of potash and mono potassium phosphate at the rate of 150 g K2O/plant. The recommended fertilizer dose of 500:150:150 (N:P:K) was given through these treatments along with various fertilizers combination (viz; urea of phosphate, urea, and P2O5 acid). Nitrogen fertilizer was given from October to January months and all N, P and K were given from February to June. Each treatment was applied at 15 days interval and fruit yield and quality were measured at harvest. Results showed the fruit yield was 31.13 t/ha with fertigation of mono potassium phosphate followed by fertigation with potassium nitrate at 15 days interval. The fruit quality is also positively affected with different potash fertilizers. Highest fruit TSS (10.54 0Brix) and fruit weight (159.28 g) was observed when fertigated with potassium nitrate at 15 days interval. The highest TSS to acidity ratio was observed in fertigation of mono potassium phosphate (13.7) followed by potassium sulphate (13.1). Therefore, the use of micro-irrigation and potash (K) fertigation technique will be a sustainable solution for increasing the productivity as well as fruit quality and promoting the export and protecting the declining mandarin orchards (Shirgure et al., 2006a).

The fertilization using drip irrigation has proved very effective in sustaining the quality production of Nagpur mandarin. For evaluation of the potash (K) fertigation dose, a field experiment was conducted on 10-12 years Nagpur mandarin during 2003-06. The treatment consisted of fertigation with 20 g K2O/plant/month, fertigation with 30 g K2O/plant/month, fertigation with 40 g K2O/plant/month and fertigation with 50 g K2O/plant/month. Nitrogen and phosphorous were given from October to January and all N, P and K as per the treatments were given during February to June. The leaf nutrients status was highest in fertigation with sulphate of potash (40 g K2O/plant) at 30 days interval from February to June. The fruit yield was highest (25.52 t/ha) with fertigation of 40 g K2O/plant of potash fertigation followed by fertigation with 50 g K2O/plant at 30 days interval (23.67 t/ha). The fruit quality was influenced with different potash fertilizers. Maximum juice TSS (9.63 0Brix) and fruit weight (163.3 g) was observed with K fertigation with 40 g K2O/plant at 30 days interval. The highest TSS to acidity ratio was observed with K fertigation with 40 g K2O/plant at 30 days interval (10.0). Fertigation with 40 g K2O/plant at 30 days interval using sulphate of potash fertilizer through micro-irrigation proved to be very effective for better fruit yield and quality of Nagpur mandarin (Shirgure et al., 2006b).

13. Ferigation schedule in bearing nagpur mandarin fruit crop

- Fertilizer N, P and K dose is 500 : 150 : 150 g/plant/year
- Fertigation is from October at the interval of 15 days.

N is given in October- January and N, P and K in February– June month

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Table 1
The citrus fertigation scheduling (N: P: K) (g/plant).

Month	Date of the month	N g/plant	P_2O_5 g/plant	K_2O g/plant
October	(1)	27.77	-	-
	(16)	27.77	-	-
November	(1)	27.77	-	-
	(16)	27.77	-	-
December	(1)	27.77	-	-
	(16)	27.77	-	-
January	(1)	27.77	-	-
	(16)	27.77	-	-
February	(1)	27.77	15.0	15.0
	(16)	27.77	15.0	15.0
March	(1)	27.77	15.0	15.0
	(16)	27.77	15.0	15.0
April	(1)	27.77	15.0	15.0
	(16)	27.77	15.0	15.0
May	(1)	27.77	15.0	15.0
	(16)	27.77	15.0	15.0
June	(1)	27.77	15.0	15.0
	(16)	27.77	15.0	15.0
Total		**500**	**150**	**150**

14. Conclusions

- There are several keys to success in using fertigation for citrus production. The irrigation system must be well balanced and maintained. Water quality should be good having low levels of total dissolved solids to decrease precipitates in irrigation lines and emitters and reduce salinity stress.
- Frequent application of nutrients increases yields, growth, and nutrient uptake efficiency by the tree in some citrus regions, but has no effect on these parameters in others.
- Frequent application also reduces the potential for nitrate pollution of groundwater.
- Fertigation gives citrus growers much more flexibility in their fertilizer application timing and may be fully automated to reduce application costs.
- Fertigation may be beneficial in most of the situations due to higher fertilizer use efficiency, suitable fertigation equipment and available water soluble fertilizers.

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