24 FERTIGATION WITH DRIPPERS

A completely different approach is required when fertigation is applied through drippers. This approach also offers numerous other possibilities. The volume of soil treated has a dominant effect on the application of this technique. If double line drippers are used, the wetted zones overlap and a continuous wet strip is fertigated. Depending on the dimensions of the wetted strip, especially in clayey soil, this method will not differ much from fertigation with microjets. The difference lies in pH control and the application of P and Mg.

When the wetted zones form individual drippers do not overlap, the application of fertilisers need to be split even further. With the OHS, fertilisers need to be applied with every irrigation between July and March even if more than one irrigation might be required per day.

Fertigation with drippers can have many advantages and in the Sundays River Valley the following have been high-lighted:

- Absorption of K by the trees can be improved and less expensive foliar sprays are required.
- The control of iron deficiencies is cheaper
- P applications are more effective.
- Nematode and *Phytophthora* control is more effective and cheaper.
- Systemic insecticides can be better utilised. - Ca applications can be done more effectively.
- Old trees respond quicker to treatments.
- Canopy and root systems react faster to treatments.

However, some practical problems arise namely:

- Preparation of nutrient mixtures.
- Different cultivars planted in the same orchard cannot be treated differently.
- The specific requirements of every orchard make logistics a nightmare.
- Water soluble fertilisers are more expensive.

The primary advantage of hydroponics is that manipulations can be done easier and more effectively to satisfy the requirements of the trees. However with hydroponics the buffer against errors is so much smaller.

A few other comments can be helpful in the operation of fertigation with drippers.

- Gypsum, but not lime, can be applied in small basins below each dripper to supply Ca and S. Lime cannot be applied like this. Lime will precipitate all P, Zn, Cu, Fe and Mn from the nutrient solution.
- When mixing chemicals, the acids must be added firstly, then the liquids, then neutral salts and lastly the alkaline materials. Thereafter the pH must be corrected.
- Physiological drought (high osmotic potential due to high concentrations of chlorides) can be offset by nitrates. A ratio of 1:2 me NO_3^-:Cl^- reduces the effect of Cl and a ratio of 1:1 can remove the effect completely. The limitation however is the nitrogen requirement of the trees which cannot be exceeded.
- Acidification of the irrigation water can also be done by CO_2. When the partial pressure of CO_2 is increased, more carbonic acid is formed and the pH decreases. When the pressure is lifted, the reaction will shift back and the acid is converted into bicarbonates and the pH rises. This can only be done in a closed system. When the water is emitted at the dripper, the pressure is lifted and the pH will rise. However the reaction time to complete the shifts is long enough to acidify the soil and root environment. That is why this method of acidification can only successfully be applied with drippers.
  $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
- In calcareous soils (soils rich in lime) the $H^+ + HCO_3^-$ will react with the carbonates of calcium to form the soluble bicarbonates that can be leached.

$H^+ + HCO_3^- + CaCO_3 \leftrightarrow Ca(HCO_3)_2 \leftrightarrow 2HCO_3^- + Ca^{++}$

With the introduction of hydroponics to commercial citrus orchards, many attempts to synchronise the phenology and nutrition were proposed. Various presentations are available and one is given in Table 47 but please note that it is only applicable in hydroponics where the root volume is restricted to less than 200 litres per tree. With early cultivars like satsuma, the concentrations of the nutrients, especially nitrogen during Phase 4 should be changed to that of Phase 5 by the end of January.

Table 47. Phenological phases in the development of citrus fruit and the concentrations of N, P and K to be applied.

Phase	Period	Phenology	Days	ppm N	ppm P	ppm K
1	End of harvest until bud break	Cell differentiation and accumulation of carbohydrates.	40-45	25	5	20
2	Bud break to first open flowers	Bud break, flowering and fruit set	40-45	45	7	50
3	Blossom to fruit drop in November.	Fruit set and cell growth	90	30	3	15
4	Fruit drop to end January/February	Fruit growth	70-100	90	3	45
5	Till end of harvest	Ripening and harvest	60-90	0	10	70

The application of nitrogen can also be split according to visual stages of the tree (Tables 48 and 49).

Table 48. Distribution of nitrogen according to visible parameters of the physiological stages of early cultivars.

Stage	Duration in week	% N required
Eight weeks prior to end of harvest	9 to 13	0
End of harvest to 6 weeks prior to bud break	5 to 9	5
6 weeks prior to bud break to full bloom	6 to 8	30
Bloom to fruit drop	6 to 8	20
Fruit drop to 8 weeks prior to harvest	15 to 25	45

Table 49. Distribution of nitrogen according to visible parameters of the physiological stages of late cultivars.

Stage	Duration in weeks	% N Required
Six weeks prior to bud break	6 to 8	35
Full bloom to fruit drop	6 to 8	20
Fruit drop to end March	22 to 24	35
Beginning of April to 6 weeks prior to bud break	12 to 18	10

Assuming that the trees require ±7500m^3 water per ha the following volumes can be calculated (Table 50).

Table 50. Guideline for the distribution of water over a 12 month period.

Month	% of total	Month	% of total
July	4,7	January	11,7
August	6,0	February	11,0
September	7,8	March	9,1
October	9,7	April	7,3
November	11,0	May	5,7
December	11,7	June	4,7

These will vary according to the prevailing climate but it gives guidelines for planning the water capacity of the system.

When the water requirement is divided according to the physiological phases, the following serves as guidelines (Table 51).

Table 51. The distribution of water according to the different physiological phases of early cultivars.

Stage	Length in weeks	% water required
Eight weeks prior to end of harvest	9 to 13	15
End of harvest to 6 weeks prior to bud break	5 to 9	7
6 weeks prior to bud break to full bloom	6 to 8	15
Bloom to fruit drop	6 to 8	18
Fruit drop to 8 weeks prior to harvest	15 to 25	45

For late cultivars the distribution is slightly different (Table 52).

Table 52. The distribution of water according to the different physiological phases of late cultivars.

Stage	Length in weeks	% water required
Six weeks prior to bud break	6 tot 8	15
Full bloom to fruit drop	6 tot 8	18
Fruit drop to end March	22 tot 24	45
Beginning of April to 6 weeks prior to bud break	12 tot 18	22

During a heat stress, the regulation of stomata functions can be better done through the combination of K and Ca. Reducing the concentration of Ca and keeping that of K constant will decrease the osmotic pressure which will help to reduce the stress. During hot weather more water is transpired and therefore more nutrients are absorbed, but the requirement is not more. Therefore by reducing the concentration, especially that of Ca, will alleviate the stress and trees will be able to absorb the water better.

The opposite is also true. During cold and wet weather, the concentration of the nutrients, especially Ca must be increased so that the same mass of nutrients is still absorbed per day. During August to November the Ca concentration should be increased. When the evapotranspiration doubles, the concentration of the nutrients can be halved, and vice versa in order to keep the total mass of nutrients supplied per day the same.

Under normal conditions, changing the concentrations of the individual elements should be done with the least change to the EC of the solution. This can be done by using K and Mg as “buffer” ions. Because these two are mobile in the plant, they can be stored. During periods of high demand for N and Ca, the concentrations of K and Mg can be reduced to keep the EC constant. Otherwise, change the EC stepwise over an extended period.

When only NH_4^+-N is supplied, more anions are absorbed in order to keep electrical neutrality. (Table 53).

Table 53. Difference in the number of molecules of K, Ca, Mg absorbed when all the nitrogen is supplied as nitrate or ammonium.

	Cations	**Anions**		**Cations**	**Anions**
N as ammonium	8 NH_4^+	9 H_2PO^-	N as nitrate		8 NO_3^-
	4 K^+	3 SO_4^{--}		8 K^+	5 H_2PO^-
	1 Ca^{++}	1 Cl^-		2 Ca^{++}	1 SO_4^{--}
	1 Mg^{++}			2 Mg^{++}	1 Cl^-
Number of charges	16	16	Number of charges	16	16

Other considerations when fertigation is done by drippers are as follows.

- Nett photosynthesis is maximum at concentrations of 3,50mg Fe and 1,85mg Mn per litre.
- In respect of changing the pH around the root, the response to the absorption of phosphate ($H_2PO_4^-$ en HPO_4^{--}) and sulphate (SO_4^{--}) is similar to that of nitrate. The difference is that much less P than N is required, about 10 times less and the change in pH is small.
- Increase the concentrations of P and K during fruit growth (phases 2 to 4) and keep the N constant.
- Root growth stops at temperatures <12°C, water stress > 50kPa and an air content <9%
- Gypsum but not lime, may be placed in small basins below each dripper to supply Ca. Lime will precipitate elements like P, Zn, Cu, Mn and Fe.
- The water soluble MAP is prepared using super phosphoric acid and contains 26% P. The combination of NH_4^+ and $H_2PO_4^=$ stimulates root growth.
- CMS (Concentrated molasses stillage) can be used in fertigation programmes. It contains organic material and about 1% N, 1%P and 5%K.
- Volatilisation of NH_4^+-N will occur when ammonium containing fertilisers are dissolved in alkaline water.

When fertigation is done without the micro-nutrient elements the roots grow mainly between the dripper. When the micro-nutrients are included, the roots will also grow below the drippers. Various formulations of micro-nutrient mixes are available. These mixes will not be able to satisfy all requirements, especially not that of boron. The concentration of boron in the irrigation water should be considered when preparing the micro-nutrient mix. Too much boron is phytotoxic. Concentrations of more than 0,25 mg B per litre is potentially dangerous. The formulation of Hoagland (1950) is still the benchmark for solutions of micro-nutrients (Table 54). Concentrations of half the Hoagland solution, is generally recommended for permanent crops.

Table 54. The concentration of micro nutrient elements in Hoagland's solution.

Element	Half strength mg/litre	Full strength mg/litre
Cu	0,015	0,025
Fe	2,500	5,000
Mn	0,250	0,500
Zn	0,025	0,050
B	0,250	0,500
Mo	0.005	0,010

Table 55. Solubility of some fertilisers suitable for fertigation.

Product	Formula	Solubility in gram per litre
Ammonium nitrate (34% N)	NH_4NO_3	180
Ammonium sulphate (21% N)	$(NH_4)_2SO_4$	705
Calcium nitrate (% Ca 12% N)	$Ca(NO_3)_2$	1210
Urea (46% N)	NH_2CONH_2	1000
Mono-ammonium phosphate (12% N 26% P)	$NH_4H_2PO_4$	227
Potassium chloride (50% K)	KCl	345
Potassium nitrate (13% N 38% K)	KNO_3	130
Potassium sulphate (45% K 23% S)	K_2SO_4	120
Mono potassium phosphate (24% P 28%K)	KH_2PO_4	330

Applying the following when preparing the nutrient solutions will make the operation less risky.

- Fill the container to 70-75% capacity before the chemicals are added.
- Firstly, add the acids, then the liquids followed by the neutral salts and then the alkaline ones.
- Ensure that the chemical was properly dissolved before the next one is added. Remember that some chemicals like phosphoric acid has a density of >1,50 and will go straight down to the bottom when added.
- Stir the solutions using and up-down-action and not just swirling in circles.
- Add the acids while the solution is constantly being mixed.
- Add the neutral salt slowly and ensure that it dissolves at the rate of application.
- Never mix an acid with active chlorine.
- Never mix concentrated fertilisers.
- Do not mix calcium salts and sulphates in concentrations exceeding single strength (Single strength is the concentration that should reach the trees).
- When uncertain about compatibilities, do the "bottle test".

Bottle test

Consider the bottle as a replica of the mixing tank. Use a 5 litre clear plastic bottle. Fill it to 75% capacity. Add the chemicals one at a time in the same ratio of mass/volume to water and ensure that the first one is completely dissolved before the next one is added. Leave the mix for 24 hours and observe any precipitation at the bottom. If no sediment is present and the solution is clear, then the two chemicals are compatible in that ratio and dilution.

Factors that determine the efficiency of a fertigation system.

- Quality of the irrigation system
- Volume soil treated.
- Distribution of phosphate.
- Splitting of applications based on clay content and volume of soil treated.
- Distance of the point of introducing the fertilisers to the orchard. The mass fertilisers remaining in the piping is important.
- Mixture of cultivars served by the same water and fertiliser pumps.