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Fertigation of vegetables in Western Australia

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FERTIGATION OF VEGETABLES IN WESTERN AUSTRALIA



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Use of Fertigation in Vegetables in Western Australia

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1. General

Fertigation is the technique of using soluble fertilisers to supply essential nutrients to vegetables through sprinkler or trickle irrigation systems, or by means of a boom spray. It is ideally suited to most horticultural areas in Western Australia, especially the sandy soils of the Swan Coastal Plain that have a poor capacity to retain nutrients.

Before and after planting, nutrients are often applied to vegetables on soils of the Swan Coastal Plain by applications of poultry manure* or solid fertilisers. After planting, fertigation is a safe and effective method of applying top-dressings of nutrients to crops, especially after the rows have closed over. If required, all of the essential nutrients needed by plants (*see section 3*) may be applied by fertigation after planting.

With sprinkler irrigation systems, fertigation is mainly used to supply nitrogen and potassium, but magnesium, calcium and some trace elements may be needed on some crops. With trickle irrigation systems, which are being increasingly used for production of capsicums, cucurbit crops, strawberries and tomatoes on the Swan Coastal Plain, fertigation is sometimes used to supply all nutrients on a regular basis.

1.1 Advantages of fertigation, compared with application of solid fertilisers

- Savings in fertilisers, fuel, labour and equipment. Various research reports indicate that 25 to 50 per cent less fertiliser may be used with fertigation, compared with the use of solid fertilisers.
- More frequent applications are possible compared with solid top dressings, especially if an automatic system is used.
- Quick absorption of nutrients from fertilisers into plants.
- Less leaching of nutrients below the root zone, when applied little and often.
- Less burning of crops, as the fertiliser is applied in diluted form.
- Fertilisers may be applied in conditions which are too wet for tractor operation.
- Less mechanical damage to the crop, when applied via the irrigation system.

1.2 Disadvantages of fertigation, compared with application of solid fertilisers

- If the irrigation system does not apply water and nutrients uniformly, then fertigation through the irrigation system may result in uneven crop growth. Over-watering will result in leaching of nutrients past the root-zone and pollution of the groundwater. Note that the use of a boom spray can be used to apply fertilisers evenly by fertigation in this situation.
- Fertilisers may settle out and block the irrigation system, especially with trickle irrigation. This may occur if the wrong fertilisers are selected. The irrigation water may also contain high contents of certain salts such as magnesium, calcium and bicarbonate which may react with some nutrients such as phosphates in the fertiliser.

- Bacterial and algal slimes may occur, due to increased levels of nutrients in the water especially with trickle systems. These will block the system, especially if they can develop on suspended particles such as iron.
- Weed problems may be greater, compared with banding of solid fertilisers, when sprinklers are used.
- More water may be applied
- Overdosing of crops with mixed maturities under a single shift of sprinklers. This does not apply to boom-spraying.
- Disease problems may be higher when sprinklers are used.

2. Selecting fertilisers for fertigation

A fertiliser suitable for fertigation for a particular crop should have the following characteristics:

- Supplies the correct nutrients for increased yields or quality.
- Be cost efficient.
- Soluble in water.
- Not react adversely with other fertilisers or salts in the irrigation water.
- Contain low levels of chloride.

3. Nutrients

The 12 nutrients essential for plant growth which are available in fertilisers include the following:

3.1 Nitrogen (N)

Nitrogen is the nutrient which will normally give the maximum response in growth and yields. It is absorbed into plants mainly as nitrate nitrogen, but ammonium nitrogen is also absorbed.

3.1.1. Ammonium nitrogen

When applied in fertilisers, ammonium ions may be absorbed directly by roots, but may also be converted to nitrate ions within three weeks in warm moist soil.

Ammonium ions will compete with calcium, magnesium and potassium for uptake into the roots. Excessive amounts of ammonium or potassium in the soil may therefore decrease calcium uptake in the plant. This may lead to blossom end rot and tip burn in tomatoes, capsicums, cauliflowers, lettuces and other vegetables, because these disorders are partly due to a shortage of calcium within the plant.

Ammonium nitrogen is directly supplied by fertigation as follows:

- Ammonium nitrate or calcium ammonium nitrate.
- Sulphate of ammonia.
- Urea. Above a soil temperature of 5°C, urea is catalysed by an enzyme to form ammonium ions within two to seven days. However, the conversion from ammonium ions to nitrate ions is rapid.

3.1.2. Nitrate nitrogen

Nitrate nitrogen is not held strongly on exchange sites. This means that if it is not absorbed by plants, it is readily lost by leaching into the lower depths of the soil.

Nitrate nitrogen is directly applied by fertilisers containing nitrates and indirectly applied from urea and all fertilisers containing ammonium.

Vegetable trials at Carnarvon and Manjimup compared ammonium nitrate, urea and sulphate of ammonia as sources of nitrogen. There were no significant differences in yields when the same amount of nitrogen was applied. Similar results have been obtained with wheat crops in Western Australia. This indicates that urea is the best choice for fertigation of nitrogen as it is the cheapest source of nitrogen. In practice, urea and ammonium nitrate are the main nitrogen fertilisers used in fertigation.

The characteristics of the main nitrogenous fertilisers for fertigation are shown in Table 1:

Table 1. Comparison of pure nitrogen fertilisers for top dressing by fertigation

Item	Ammonium nitrate ('Agran')	Sulphate of ammonia	Urea
Cost $/tonne in Perth in 2001	566	330	468
% Nitrogen	34	21	46
Cost $/tonne of pure nitrogen in 2001	1664	1571	1017
Main advantages	Quick-acting Very high solubility (191 kg/100 L).	It is mainly suitable for fertigation on alkaline soils, as it will decrease pH more than urea or ammonium nitrate. High solubility (71 kg/100 L).	39% cheaper than ammonium nitrate, per unit of nitrogen. High solubility (105 kg/100 L).
Main disadvantages	Needs special transport requirements (may explode during trucking or storage in combination with distillate or oil). Higher salinity hazard than urea or sulphate of ammonia.	Increases acidity of acid soils. Should not be applied to recently limed soils due to nitrogen loss. May increase problems with tip burn and blossom end rot.	May burn crops if applied at too high rates

The characteristics of other nitrogenous fertilisers used in fertigation are shown in Table 2:

Table 2. ***Comparison of other nitrogen fertilisers for top dressing by fertigation***

Item	Calcium Ammonium nitrate	Calcium nitrate	Mono ammonium-phosphate (technical grade)	Polyfeed standard	Potassium nitrate
Cost $/tonne in Perth in 2001	470	770	1,200	1,880	1,220
% Nitrogen	27	15.5 to 17.0	12	19	13.4
Cost $/tonne of pure nitrogen in 2001	1,740	4,529 to 4,967	10,000	9,894	9,100
Other nutrients	7 to 14 % calcium	19% calcium	22.6% phosphorous	8.4% phosphorous, 15.8% potassium and the six main trace elements	39% potassium
Comments	Suitable for acid soils	Applied to leaves of some crops, ie. strawberries, lettuces, celery to supply calcium. Good solubility. Has a neutral effect on pH	Ordinary grade is less soluble		Commonly used in fertigation
Main disadvantages	Not suitable for alkaline soils	Highly hygroscopic**	Water high in calcium or magnesium will cause settling out		

3.2 Phosphorus (P)

Phosphorus is an important nutrient which is required for root development, cell division, quality and yield. It is usually applied before planting, in the form of poultry manure*, or solid applications of mixed fertilisers, or superphosphate. It is usually applied before planting, but may also be applied after planting on some sandy soils, such as Bassendean and other grey sands.

Leaching of phosphorus is a major problem on soils of the Swan Coastal Plain. This results in death of marine creatures and a build up of blue-green algae and odours in waterways due to high phosphorus levels. Many sources of phosphorus fertiliser are difficult to dissolve in water, especially superphosphate (solubility of 2 kg/100L).

Phosphorus fertilisers have little effect on the pH of the soil and have a low salt index. Phosphorus is not commonly used in fertigation, especially in sprinkler irrigation systems, but if required the following sources of phosphorus for fertigation may be used:

Table 3. Comparison of phosphorus fertilisers for fertigation

Name	% Phosphorous	Cost $/tonne in 2001	Cost $/tonne of pure phosphorous in 2001	Other nutrients	Comments
Mono ammonium phosphate (technical grade which is soluble)	22.6	1,200	5,310	12% nitrogen	Main phosphorus source used in fertigation.
Phosphoric acid	27.0	2,610	9,670	Nil	Corrosive acid. Mainly suitable for trickle systems as a fertiliser and cleansing agent.
Polyfeed Standard	8.4	1,880	22,380	9.0 % nitrogen, 15.8% potassium and the 6 main trace elements	

3.3 Potassium (K)

Potassium is usually absorbed by plants more than any other nutrient. It is an important nutrient for quality, and to make the plant more resistant to diseases and drought.

Potassium leaches through the soil more than phosphorus, but less than nitrogen. There have been no problems so far with high levels of potassium leaching into the ground water, either in drinking water supplies or with marine life in waterways.

There is competition with other positively charged ions such as calcium, magnesium and ammonium ions for absorption into the plant. High amounts of potassium may lead to more problems with tipburn, blossom end rot and magnesium deficiency in various crops.

Potassium fertilisers have little effect on soil pH.

Solubility of fertilisers containing potassium is lower than nitrogen, but much higher than phosphorus fertilisers. Some sources of potassium fertilisers may vary in solubility.

The main sources of potassium for fertigation are as follows:

Table 4. Comparison of potassium fertilisers for fertigation

Name	% Potassium	Cost $/tonne in 2001	Cost $/tonne of pure potassium in 2001	Comments
Muriate of potash (potassium chloride)	49.8	495	990	Fairly good solubility (35 kg/100 litres at 20°C). Coarse particle size may cause blockages and wear in pumps. Cheapest source of potassium. Slightly hygroscopic**
Potassium nitrate (standard crystal grade)	38.2	1,200	3,140	Excellent fertiliser for supplying nitrogen and potassium by fertigation. Fairly good solubility (32 kg/100 L). Dissolve in hot water in cold weather. Low salinity hazard.
Sulphate of potash (standard crystal or fine grade is better than granular grade)	41.5	730	1,760	78% more expensive than muriate of potash, but usage is increasing in fertigation. Fair solubility of 11 kg/100 kg. May dissolve poorly or settle out in cold weather (dissolve in hot water).
Polyfeed Standard	15.8	1,880	11,900	Also contains 19.0% nitrogen, 8.4% phosphorus, and 6 main trace elements
Polyfeed High K	32.3	1,980	6,140	Also contains 12.0% nitrogen, 2.6% phosphorus and 6 main trace elements

3.4. Calcium (Ca)

Calcium is usually available in good supply in soils and is often not applied in fertiliser programs. It is often added to acidic soils as lime to increase the pH.

It is an immobile nutrient in the plant and there are often problems with supply of calcium to fruits and leaves especially under certain climatic conditions (i.e. high temperatures). Poor movement of calcium within the plant contributes to blossom end rot in tomatoes, capsicums and water melons and tip burn in celery, lettuces and brassica crops.

Calcium nitrate (see Table 2) is often fertigated onto the soil or leaves to correct the above problems. However, control is not easy as the calcium may be supplied too late and it is difficult to apply to the heart leaves of some vegetables.

3.5 Magnesium (Mg)

Magnesium is usually absorbed by plants more than phosphorus and is often deficient in vegetable crops, especially where there are high levels of calcium and potassium.

Magnesium deficiency is readily corrected by fertigation (see Table 5):

Table 5. Comparison of magnesium fertilisers for fertigation

Name	Cost $/tonne in 2001	% Magnesium	Cost $/tonne of pure magnesium in 2001	Comments
Magnesium sulphate (Epsom salts)	550	9.6	5,730	Often applied. Slightly hygroscopic**
Magnesium nitrate	1,440	9.3	15,480	Seldom used in fertigation. Also contains 10% nitrogen.

3.6 Sulphur (S)

Deficiency of sulphur is rare as the nutrient is a constituent in many types of fertilisers, i.e. superphosphate, various sulphates (potassium, magnesium and some trace elements) and NPK mixtures. The sulphate forms of various fertilisers are often used in fertigation.

3.7 Trace elements

Trace elements are nutrients needed by plants in minute quantities. They are therefore applied in small amounts and costs are not high.

Boron, iron, manganese and zinc are likely to be deficient in alkaline soils, and molybdenum in acid soils. Copper, manganese and zinc are often applied in fungicides to control diseases and are therefore indirectly applied as trace elements to crops.

There is a danger of toxicities with boron and molybdenum or induced deficiencies (i.e. phosphorus deficiency caused by too much iron), if some of these are applied at excessive rates.

Trace elements may be applied by fertigation. Some trace elements are sold in the chelated form. Nutrients in this form may be slightly more available than the ordinary form, but often the non-chelated forms give equally good results and are much cheaper. Some of the trace elements which are used in fertigation are shown in Table 6, but this is not an exhaustive list.

Table 6. Trace elements for use in fertigation

Trace element	Fertilisers
Boron (B)	Borax, Solubor, Polybor, Spray Boron
Copper (Cu)	Copper sulphate
Iron (Fe)	Iron chelate, Sequestrene, Ferrous sulphate
Manganese (Mn)	Manganese sulphate, Mantrac, Tecmangan
Molybdenum (Mo)	Sodium molybdate
Zinc (Zn)	Zinc sulphate, Zincsol, Zintrac

4. Mixed fertilisers

There are a large number of solid fertilisers containing nine to twelve of the essential applied nutrients needed by plants, and these are usually based on good levels of nitrogen, phosphorus and potassium.

Mixed fertilisers are only occasionally applied through sprinkler irrigation systems, but not through trickle irrigation systems. This is because mixed NPK fertilisers are more expensive than using individual nutrients, have low solubility and may cause blockages in the irrigation equipment. Nitrophoska Perfect (15% nitrogen, 2.2% phosphorus, 16.6% potassium and 1.2% magnesium, plus trace elements) is the most soluble NPK fertiliser and is the NPK fertiliser that is most used for fertigation.

5. Fertigation equipment

Selection of fertigation equipment is described in a separate farmnote 35/01 released in 2001.

6. Operation

Fertilisers for fertigation may be purchased in the solid or liquid forms. Liquid fertilisers are easy to use and handle, but are not normally used as they are more expensive than solid fertilisers.

Some fertilisers may be sold in various grades. Ordinary grade is the cheapest material and is usually suitable for fertigation, but may contain some impurities. Occasionally, it may be necessary to purchase some fertilisers in the more expensive technical grade if better solubility is required, especially for trickle systems (i.e. mono ammonium phosphate).

Some fertilisers may require stirring in the tank or initial dissolving in hot water, especially in cold weather. Many systems incorporate by-pass agitators to ensure good mixing of the fertilisers. Do not apply fertilisers to the tank until it is half full.

Fertiliser is applied in the final stages of irrigation, in order that most of the fertiliser is retained within the rooting zone of the plant. Fertigation normally takes 10 to 20 minutes.

Water is applied for two to five minutes after fertigation to wash the fertiliser off the plants into the soil and to prevent damage from fertilisers to the pump, pipelines and valves. This especially applies to urea, which may clog the system if it is not flushed out.

Commence fertigation immediately after planting with transplanted crops and on emergence with seeded crops, but if poultry manure* has been used, fertigation or the use of solid fertilisers as top-dressings should begin two to three weeks after planting. Fertigation may be used for the whole period after planting, or used when the rows close over.

Growers usually fertigate every three to seven days, but with automatic systems and using trickle irrigation they may fertigate daily or every two days.

Remember to continue fertigation during rainy periods.

The irrigation system should allow different fertigation rates to be applied to different crops, or crops at different growth stages. Where this is not possible, other methods such as banding may be required.

Nitrogen and potassium are the nutrients that are most commonly applied by fertigation. The rates and costs of these nutrients are therefore listed in Tables 7, 8 and 9.

7. Applying various rates of nitrogen and potassium by fertigation

The rates of three types of nitrogen and three types of potassium fertilisers that need to be applied to supply three individual rates of nitrogen and potassium are shown in Table 7.

Table 7. Applying various rates of nitrogen and potassium by fertigation

Rate kg/ha of pure nitrogen or potassium (kg/ha)	Amount of fertiliser kg per hectare	
	Nitrogen	Potassium
15	44.1 kg ammonium nitrate 32.6 kg urea 71.4 kg sulphate of ammonia	30.1 kg potassium chloride (muriate of potash) 36.1 kg potassium sulphate 39.5 kg potassium nitrate
25	73.5 kg ammonium nitrate 54.3 kg urea 119.0 kg sulphate of ammonia	50.2 kg potassium chloride (muriate of potash) 60.2 kg potassium sulphate 65.8 kg potassium nitrate
35	102.9 kg ammonium nitrate 76.1 kg urea 166.6 kg sulphate of ammonia	70.3 kg potassium chloride (muriate of potash) 84.3 kg potassium sulphate 92.1 kg potassium nitrate

The ratio of nitrogen to potassium for most crops, with the exception of broccoli, cabbages, celery, pumpkins, silverbeet and sweet corn, needs to be approximately 1:1. Table 8 compares the costs for applying two fertilisers (A plus B) to apply 20 kg/ha nitrogen and 20 kg/ha potassium.

Table 8. Comparison of fertiliser costs to give a Nitrogen:Potassium ratio of 1:1

Fertilisers costs in 2001 to supply 20 kg nitrogen plus 20 kg potassium per hectare by applying two fertilisers (A & B) together		
Fertiliser A	**Fertiliser B**	**Total costs in 2001 $ per hectare**
39.0 kg/ha of ammonium nitrate	51.7 kg/ha potassium nitrate	84.10
25.6 kg/ha of urea	51.70kg/ha of potassium nitrate	74.00
58.8 kg/ha of ammonium nitrate	8.2 kg/ha potassium sulphate	68.50
43.4 kg/ha urea	48.2 kg/ha of potassium sulphate	55.50
58.8 kg/ha of ammonium nitrate	40.0 kg of potassium chloride (muriate of potash)	53.00
43.4 kg/ha urea	40.0 kg/ha of potassium chloride (muriate of potash)	40.10

The cheapest combination is to use a mixture of urea and muriate of potash. A combination of urea plus potassium sulphate would be the cheapest combination on chloride-sensitive crops.

Due to good solubility and no leaf scorching, the main source of potassium used by growers is potassium nitrate. The cheapest combination with this fertiliser to obtain the desired ratio of nitrogen to potassium of 1:1 for most crops is to combine potassium nitrate with urea. The amount of urea plus potassium nitrate to supply nitrogen and potassium at a ratio of 1:1 and various rates is shown in Table 9:

Table 9. Rates of urea plus potassium nitrate to give a nitrogen:potassium ratio of 1:1 at five rates

Rate kg/hectare of pure nitrogen plus pure potassium (1:1)	Urea kg/ha	Potassium nitrate kg/ha
15 kg/ha nitrogen + 15 kg/ha potassium	19.2	38.5
20 kg/ha nitrogen + 20 kg/ha potassium	25.6	51.3
25 kg/ha nitrogen + 25 kg/ha potassium	32.0	64.2
30 kg/ha nitrogen + 30 kg/ha potassium	38.4	76.9
35 kg/ha nitrogen + 35 kg/ha potassium	44.8	89.7

8. Compatibility

Fertilisers are often applied together and the most common combination is a mixture of nitrogen and potassium. Do not mix the following fertilisers as this may result in settling out of fertilisers and blocking of the system:

- Fertilisers containing calcium with sulphates or phosphates, i.e. do not apply calcium nitrate with magnesium sulphate or potassium sulphate.
- Magnesium sulphate with mono ammonium phosphate.
- Calcium hypochlorite or sodium hypochlorite are disinfectants which may be used for controlling algae, bacteria and fungi in trickle irrigation systems at a concentration of 1 ppm, especially where bacteria may develop a slime on particles of iron. They should not be mixed with nitrogen, as this will result in the formation of chloroamines which are toxic.
- Phosphoric acid should not be mixed with fertilisers containing calcium or magnesium or with copper, iron, manganese and zinc sulphates.
- Ammonium sulphate with potassium chloride.

9. Applying fertilisers through the leaves

Fertigation can also be used to apply nutrients to the leaves (foliar fertilising), where the nutrients are absorbed through the leaves and into the plant. Trials in many countries with foliar fertilising using proprietary fertilisers to supply the main nutrient needs of the plant have largely been unsatisfactory. The reasons for this are that plants are adapted to feeding through their roots. The waxy surface of leaves do not allow nutrients to be taken up quickly. Too high a concentration may also burn the leaves or reduce the efficiency of any pesticides that are often applied with fertilisers.

Feeding through the leaves cannot replace efficient feeding of nutrients into the roots from the soil, especially of the major nutrients. Trials in Victoria showed that nitrogen was the most successful foliar nutrient, followed by potassium. A mixture of potassium nitrate (1.5 kg/100 litres) plus urea (0.5 kg/100 litres) plus Agral 60 wetting agent (1 mL/litre) was superior to proprietary foliar fertilisers and was about five times cheaper. The best results were obtained under cold conditions. However, it was found that it was essential that foliar fertilisers were applied in conjunction with a balanced fertiliser supply to the soil, by application of solid fertilisers or by fertigation. Lettuce, spinach, silver beet, tomatoes, beans and radishes were the most responsive crops to foliar fertilising.

Foliar fertilising is most suitable for correcting proven deficiencies, especially due to magnesium and trace elements. In this case, identification of the deficiency and spraying with the correct nutrient may correct the problem, although with some trace elements (i.e. iron, zinc) it may be too late to correct the deficiency when it becomes visible.

Apply the following fertilisers to correct deficiencies:

Table 10. Foliar fertilisers to correct proven deficiencies

Calcium	Calcium nitrate at 8 grams per litre
Magnesium	Magnesium sulphate at 10 grams per litre
Boron	Borax at 5 grams per litre
Copper	Copper sulphate at 2 grams per litre, plus lime to prevent leaf burning
Iron	Iron chelate at 2 grams per litre
Manganese	Manganese sulphate at 8 grams per litre
Molybdenum	Sodium molybdate at 1 to 2 grams per litre
Zinc	Zinc chelate at 4 grams per litre

There are also a number of proprietary liquid fertilisers which maybe used to supply all of the six trace elements and often together with other nutrients. These are best used when the grower is unsure of the type of deficiency in the plants.

Footnotes

* From 2001 onwards, poultry manure has been banned for use in the Shires/local government areas of Gingin, Wanneroo, Joondalup, Armadale,Cockburn, Kwinana, Rockingham and Murray from September to April inclusive, but there are no restrictions in other areas throughout the year. In future, there is the possibility that it may not be available for use in horticulture in the Perth area.

** Hygroscopic-absorbs water from air, especially under humid conditions in storage.

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