14 Fertigation

This chapter provides guidance on selecting fertilizers and calculating injection rates for fertilizer application through a trickle irrigation system. Considerations for safety and proper system operation are also given. The manual, “Chemigation Guidelines for British Columbia” available from the Ministry of Agriculture and Food provides additional information that is pertinent to this topic.

Trickle irrigation systems provide a good method of applying fertilizers, nematocides and other chemicals. Advantages of applying fertilizers through a trickle irrigation system include:

- The high application efficiencies of these trickle systems ensure even and uniform application of the fertilizer.
- Since the fertilizer is applied directly to the plant’s root zone, maximum availability and efficiency can be obtained.
- Labour, machinery and fuel savings are achieved over conventional fertilizer application methods/
- Nutrients can be applied during the growing season with precalculated amounts and frequencies to meet the demands at various growing stages. This is especially important for chemicals that are susceptible to leaching loss, which may cause late season nutrient deficiency.
- In drier climates, applying the fertilizer through a trickle system ensures that the fertilizer will be incorporated into the soil.

To control plugging and potential compatibility problems between fertilizers, the following points should be considered when applying nutrients or chemicals through a trickle irrigation system:

- Chemicals must be readily soluble.
- If more than one fertilizer is to be applied at one time, check to ensure that they are compatible and will not form a precipitate in the irrigation lines. See Table 14.2 for a compatibility chart of different fertilizers.
- Chemicals must not corrode components of the trickle system.
- Chemicals should always be injected before the filtration unit.
- Chemicals injected must not react with elements in the water after injection. To ensure compatibility of the chemical to be injected with the irrigation water, a simple test can be conducted before injecting the chemical. Add a small amount of the chemical to be injected to a jar filled with water from the irrigation system. Ensure that the concentration will be slightly higher than the solution anticipated in the system. Shake well and leave for 24 hours. If a reaction has occurred during this period the chemical is not recommended for injection.

14.1 Safety Precautions

The introduction of chemicals into an irrigation system presents a potential hazard to public health. The irrigation system acts as a cross connection between the chemical solution tank and the potable water source. The cross connection can be to an irrigation district mainline, municipal water line, stream, lake, river or groundwater. Most of British Columbia's fresh water supplies are considered a potable water source.

A direct connection between a potable water system and a non-potable system is subject to backflow conditions due to either backsiphonage or backpressure.

Backsiphonage

Backsiphonage is caused by low pressure or a reduced pressure in the supply piping. Principal causes of backsiphonage are:

- Creation of a severe hydraulic gradient by undersized piping in the supply line.
- Pipeline breakage in the district mainline that is lower than the customer service point.
- Reduced mainline pressure due to a high water withdrawal rate such as fire fighting or mainline flushing.
- Reduced mainline supply pressure due to pump or power failure.

Backpressure

Backpressure occurs when the user system is operating at a higher pressure than the potable water supply system. Major sources of backpressure are:

- Booster pumps on the user system used to increase flows and pressure requirements.
- Interconnection with other piping systems operating at higher pressures.
- Connections to a pressurized system such as a boiler.

In trickle irrigation systems backpressure can be caused by large elevation differences in the system and the use of injection pumps that create higher pressures.

Degree of Hazard

The safety devices that must be installed on an irrigation system will depend on the degree of hazard the system imposes on potable water supplies. There are three degrees of hazard that must be considered.

Severe

An existing or probable cross connection involving any substance in sufficient concentration to cause death, spread disease or has a high probability of causing such effect.

Moderate

An existing or probable cross connection involving any substance that has a low probability of becoming a severe hazard but constitutes a nuisance or is aesthetically objectionable if introduced into the water supply.

Minor

An existing or probable cross connection between a potable water supply line and a tank or other water supply that has a low probability of becoming contaminated.

A chemical injector installed on an irrigation system is considered a severe hazard as fertilizers, herbicides or insecticides could be introduced into the potable water supply system. The irrigation system is generally always cross connected to a potable water supply. These may be surface water supplies, groundwater, irrigation districts or municipal water systems. An approved backflow prevention device must be installed on all irrigation systems that are

Backflow Preventor from Watts® Regulators

Figure 14.1 *Reduced Pressure Principle Device*

injecting chemicals. A Reduced Pressure Principle Device is considered to be the best standard for an approved backflow preventor. See Figure 14.1.

Additional Precautions

The safety requirements for injection systems will depend on many circumstances. These include:

- water supply source
- irrigation system pressure source
- type of injector

- chemical injected
- type of irrigation system

The application of pesticides, herbicides and insecticides are considered much more hazardous than general fertigation. Additional precautions must therefore be taken for the application of these products. If applying a pesticide, herbicide or insecticide the following procedures must be followed:

- The product label must clearly specify that the product can be applied through an irrigation system. Applying a product through an irrigation system that does not have this method of application specified on the label is an offence under the Pesticide Control Act.
- Pesticides, herbicides, insecticides, fertilizers or surfactants when applied through an irrigation system cannot be mixed or combined with other products.
- Only positive displacement pumps or venturi injection systems that are compatible with the chemical to be injected can be used.
- Irrigation must not be carried out for at least 24 hrs after chemigation has been completed to allow time for the active ingredient to work.
- Application of these chemicals through an irrigation system cannot occur if the target area is within 30 metres of a residential dwelling, park, playground, stream, river, or lake.

14.2 Injection Methods

Trickle irrigation systems can utilize numerous injection methods. The type of injectors that are recommended are venturis, ratio feeders, and electric or water driven injector pumps. Factors which affect the type of injector to select includes cost, available power source, reliability, chemical to be injected, number of chemicals to be injected simultaneously and the ease of regulating the injection rate.

Venturi Injectors

Venturi injectors operate on the principle that a pressure drop accompanies the change in water velocity as it passes through a constriction. Atmospheric pressure forces the chemical into the line at this reduced pressure zone. These types of systems are not effective for low pressure situations as they have a significant head loss across them. In some situations venturi systems are assisted by a small pump to ensure sufficient pressure difference is available to allow for proper operation. The pump and venturi are installed on a line that is in parallel to the irrigation system supply lines. Table 14.1 indicates typical injection rates that can be achieved with a venturi injection system. Figure 14.2 shows a venturi injection system.

Figure 14.2 *Venturi Injector*

Table 14.1	Venturi Injector Selection				
Model	Size In/Out	Pressure Differential	Flow Through Injector @ 50 psi (gpm)	Injection Rate	
				L/hr	gal/hr
283	1/2"	26%	0.5	23	6
287	1/2"	22%	0.9	30	8
384	1/2"	25%	2.1	38	10
484	1/2" -3/4"	18%	3.4	64	17
584	3/4"	18%	6.4	95	25
878	1"	16%	12	227	60
1078	1"	16%	17	284	75
1583	1 1/2"	18%	34	680	180
2081	2"	18%	101	1890	500
384-x	1/2"	50%	2.1	132	35
885-x	1"	32%	12	530	140
1585-x	1 1/2"	35%	36	1325	350
2083-B	2"	67%	29	4275	1130

From Mazzei Injector Corporation

Ratio Feeders

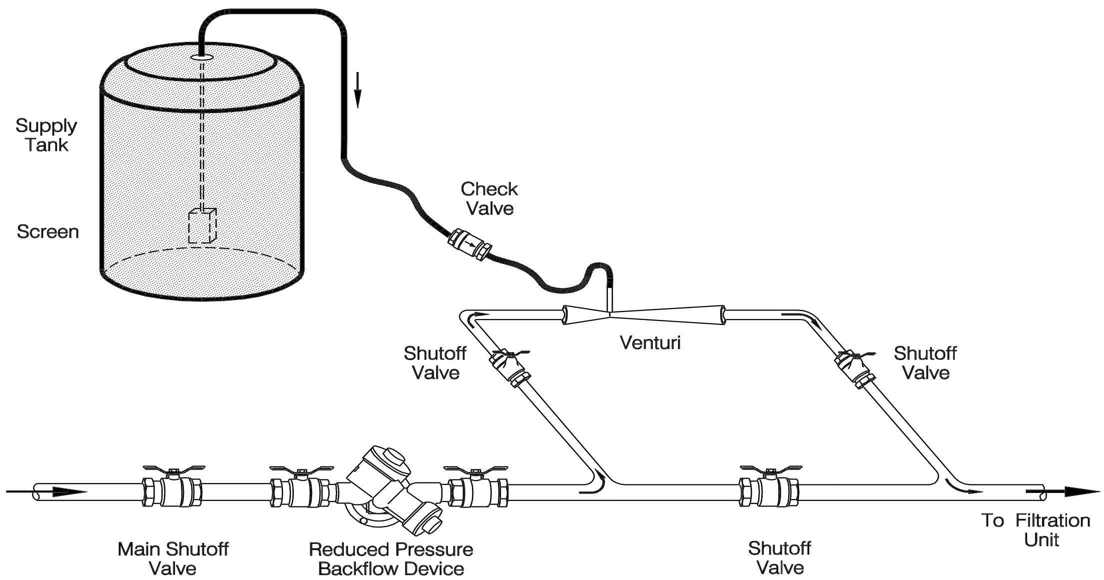
Ratio feeders are a water driven type of injector pump. The quantity of material injected will depend on the flow rate through the injector but the concentration of chemical in the irrigation water will remain the same. Therefore if the injector is set at a ratio of 1%, a zone flow rate of 100 gpm will have an injection rate of 1 gpm and a zone flow rate of 50 gpm will have an injection rate of 0.50 gpm.

Since the proportion of chemical injected does not vary with the system flow rate or operating pressure, these types of injectors can be used in situations where the system automatically can change from one zone to another, providing the concentration required in each zone is the same.

Ratio feeders generally operate at injection ratios from 0.2% to 2%.

Venturi and ratio feeder systems are usually installed on a by pass line that

Figure 14.3 *Dosatron Ratio Injection System*



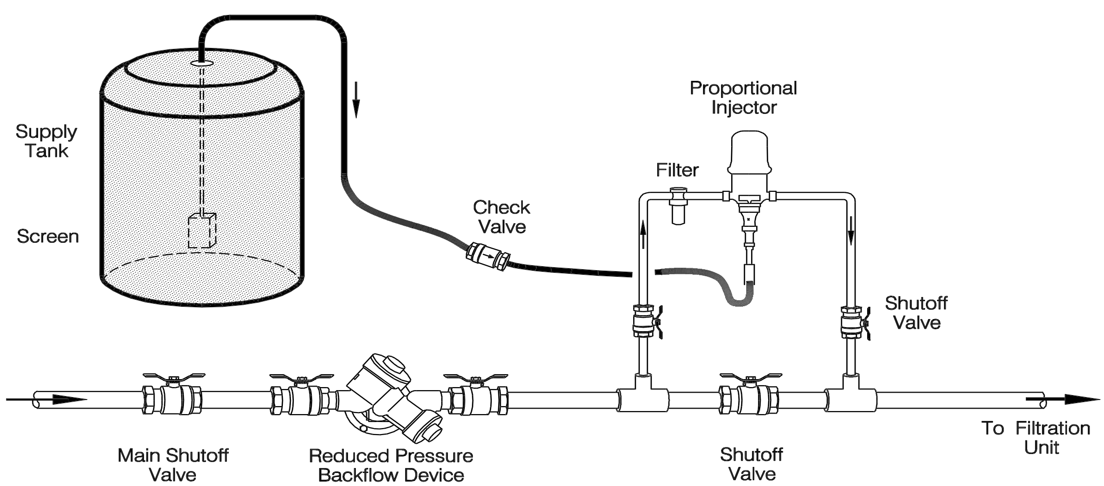


Figure 14.4 *Venturi and Ratio Feeder Installation*

runs parallel to the main irrigation line. See Figure 14.4.

Injector Pumps

Injector pumps can be either electrically-powered or water-driven. They have greater precision than any of the other injection methods but are more costly.

The injector pump provides variable speed drives to allow for a wider range of injection rates. An injector pump is capable of supplying the same concentration of chemical at a constant rate for the required duration. The pump must be made of non-corrosive material due to the nature of the chemicals injected.

An electric injector pump is capable of continuing to inject chemicals once the irrigation system has been shut down. Careful monitoring during chemical application is therefore always important. This problem can be somewhat overcome by application on a batch-per-zone basis.

Water-powered injector pumps are available in turbine (impeller) or piston drive. Piston-operated pumps use a small amount of irrigation water to drive the piston. The amount of water used to operate the piston is usually three times the quantity of the injected solution. A drain should be provided for this water. The injection rate is set by controlling the amount of water going to the drive piston. Piston-drive units do not reduce the irrigation system pressure.

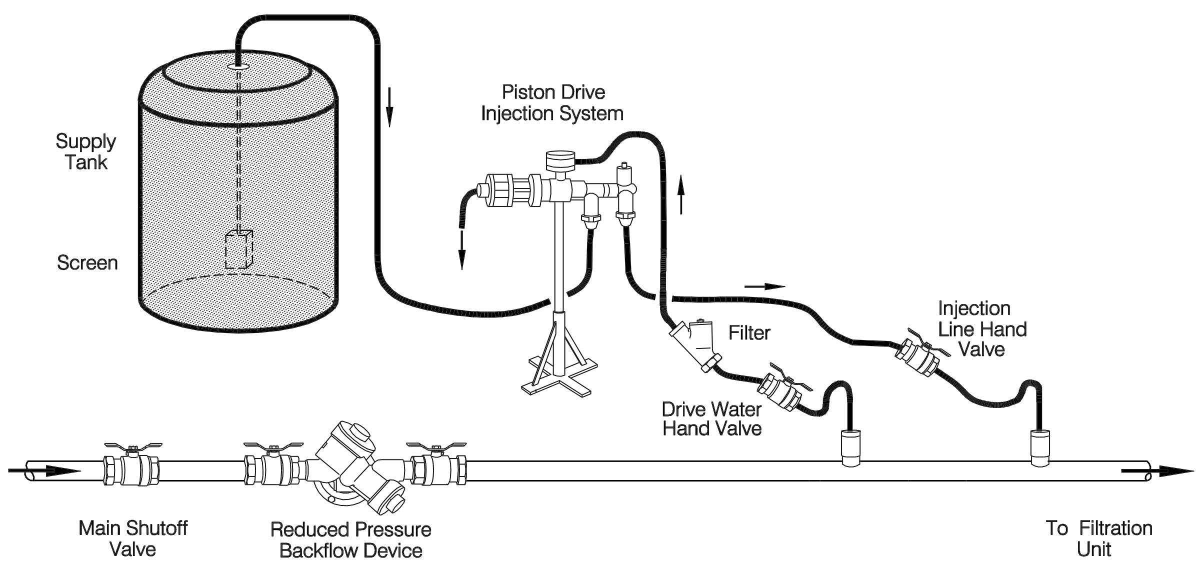


Figure 14.5 *Water Driven Injector*

Figure 14.5 shows a water driven injection system.

A turbine water-driven injector does not expel water but does utilize some of the irrigation system supply pressure. The irrigation system design must take this into account to ensure that adequate pressure is available to operate both the injector and the system. These types of injectors are available in single and double head models. Figure 14.6 shows the installation for an electric or gas driven injector.

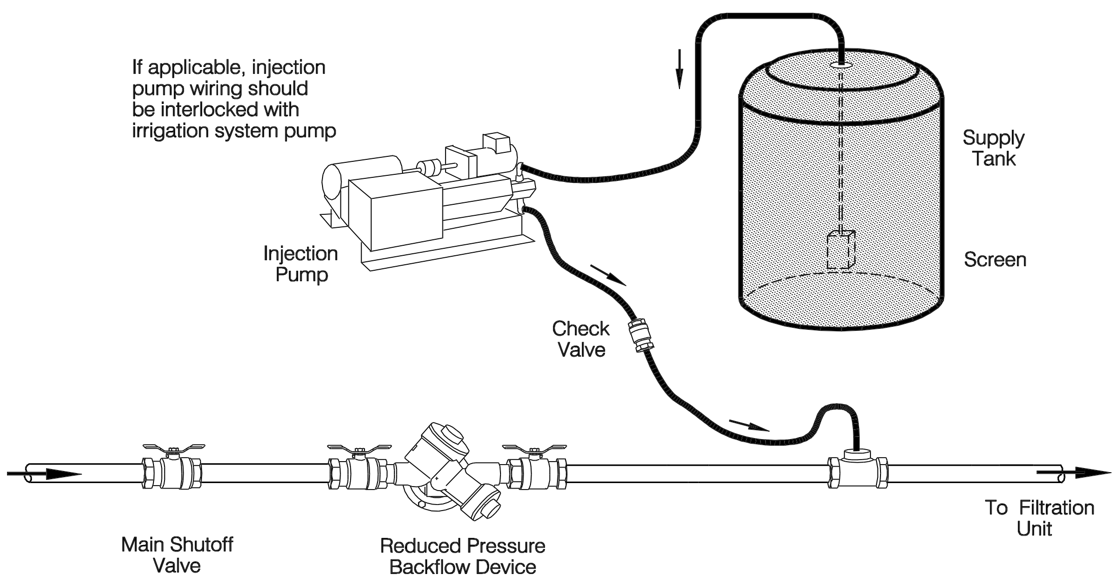


Figure 14.6 *Electric or Gas Injection Pump Installation*

14.3 Fertilizer Selection

Selection of fertilizers can be difficult as fertilizers come in various chemical formulations containing composition agents with different types of coatings, including wax. Fertilizers are available in solid or liquid forms. The selection of a solid or liquid fertilizer will depend on storage requirements, available storage facilities, product stability, ease of handling, method of injection, cost, and the acidification produced by applying the fertilizer to the soil.

Table 14.2 provides information on the calcium carbonate equivalent for various fertilizers. The calcium carbonate equivalent is the amount of calcium carbonate required to neutralize the acidity produced by the fertilizer. It is a ratio of the kg of calcium carbonate required to neutralize 100 kg of fertilizer. A larger calcium carbonate equivalents value means greater acidifying potential.

Based on their primary nutrient content (N, P_2O_5, K_20), fertilizers are given a designation consisting of three numbers. These numbers, called grades, represent the amount of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) content of the fertilizer in terms of percentage by weight. The fertilizer ratio is the relative proportion of each of the primary nutrients. For example, a 12-12-12 grade fertilizer has a 1:1:1 ratio.

To avoid damage to plant roots from high fertilizer concentrations, fertilizer concentration in the irrigation water should not exceed 5%. Although susceptibility to root burning from concentrated fertilizers varies with crops, fertilizers or accompanying irrigation practices, this upper limit should not be exceeded to ensure safe application. Generally, fertilizer concentrations of 1-2% in the irrigation water are considered acceptable.

Solid Fertilizers

To be able to apply a granular fertilizer through an irrigation system it must first be dissolved in water. The mass of fertilizer that will dissolve in a specific volume of water is known as solubility. The solubility of fertilizers may vary greatly with temperature, especially ammonium and potassium nitrates. Table 14.2 provides the solubility of some fertilizers in water at various temperatures. If the solubility of the fertilizer at ambient air temperatures is known the corresponding values should be used. Table 14.2 can be used to provide a good estimate by interpolating the data shown. The presence of other substances in the solution may either decrease or increase the solubility. **The solubility values shown in Table 14.2 should not be used for injection into a trickle irrigation system. Rather than using the value as g / 100 ml water, it is suggested that this be increased ten fold, using the same value but dissolved in a litre of water instead of 100 ml. See Example 14.1.**

Selection of a granular fertilizer will depend on the nutrient that is to be applied, fertilizer solubility and ease of handling. To ensure that fertilizers selected will not precipitate in the irrigation lines, mix the fertilizer solution with a sample of irrigation water at a slightly higher concentration than will be injected into the irrigation system. If the chemical stays in solution, then the product is safe to inject into the irrigation system. If a precipitate occurs, applying this fertilizer through the trickle system should be avoided.

Table 14.2	Granular Fertilizer Properties				
Fertilizer	**Molecular Compound**	**% Element**	**Solubility g/100 ml**	**Temp ^{0} C**	**Equivalent $CaCO_3$**
Ammonia	NH_3	82% N	90	0	148
Ammonium Nitrate	NH_4NO_3	34% N	118 187 590	0 20 80	62
Ammonium Sulphate	$(NH_4)_2SO_4$	21% N 24% S	71 95	0 80	110
Calcium Carbonate (Limestone)	$CaCO_3$		0.006	0	
Calcium Metaphosphate	$Ca(PO_3)_2$		0.001	0	
Calcium Nitrate	$Ca(NO_3)_2 \cdot 4H_2O$	15.5% N	134 364	0 100	-20
Calcium Sulphate	$CaSO_4 \cdot 2H_2O$		0.24	0	
Copper Sulphate	$CuSO_4 \cdot 5H_2O$		32	0	
Diammonium Phosphate	$(NH_4)_2HPO_4$	18% N 20% P	25	0	70
Dicalcium Phosphate	$CaHPO_4 \cdot 2H_2O$		0.02	0	
Magnesia	MgO		0.0006	0	
Magnesium Sulphate	$MgSO_4 \cdot 7H_2O$		85	0	
Manganese Sulphate	$MnSO_4 \cdot 4H_2O$		105	0	
Monoammonium Phosphate	$NH_4H_2PO_4$	11% N 22% P	43	0	58
Monocalcium Phosphate	$CaH_4(PO_4)_2H_2O$	20% P	varies		
Potassium Chloride	KCl	60% K_2O	28 51	0 80	neutral
Potassium Nitrate	KNO_3	13% N 46% K_2O	13 169	0 80	-26
Potassium Sulphate	K_2SO_4	53% K_2O	8	0	neutral
Sodium Nitrate	$NaNO_3$	16% N	73	0	-29
Urea	$CO(NH_2)_2$	46% N	67 108 167	0 20 40	71
Zinc Sulphate	$ZnSO_4 \cdot 6H_2O$		70	0	

Equivalent $CaCO_3$ - kg of $CaCO_3$ per 100 kg of fertilizer to neutralize

Liquid Fertilizers

Liquid fertilizers have generally been considered more expensive, offering only lower nutrient concentrations. The demand for liquid fertilizers has increased in many areas where they are now the predominant choice and are available in a large selection of solutions. Liquid fertilizers are easier to use for the grower as they are ready to use upon delivery to the farm.

Liquid fertilizers are available as solutions and suspensions, both of which may contain multinutrient or single nutrient materials. Solutions are defined as liquids that have all the plant nutrients in a solution, while suspensions hold part of the plant nutrients suspended in the liquid by a suspending agent.

Table 14.3	Fertilizer Solutions		
Fertilizer Solution	**% Nutrient**	**Density Kg/Litre**	**Density Lbs/Gal (U.S.)**
	Nitrogen		
Urea Solution (23%)	23% N	1.14	9.48
Urea Solution (20%)	20% N	1.12	9.33
Ammonium Nitrate	20% N	1.27	10.56
N Solution	30% N	1.27	10.56
Urea Ammonium Nitrate	28% N	1.28	10.66
Urea Ammonium Nitrate	32% N	1.33	11.06
Ammonium Nitrate Ammonia	37% N	1.19	9.91
Ammonium Nitrate Ammonia	41% N	1.14	9.48
Calcium Ammonium Nitrate	17% N		
Aqua Ammonia	20% N	0.91	7.60
Aqua Ammonia	24% N	0.90	7.47
	Phosphorus		
Phosphoric Acid	52% P_2O_5 68% P_2O_5 75% P_2O_5		
Ammonium PolyPhosphate	8% N 24% P_2O_5	1.26	10.5
Ammonium PolyPhosphate	9% N 30% P_2O_5	1.36	11.3
Ammonium PolyPhosphate	10% N 34% P_2O_5	1.37	11.4
Ammonium PolyPhosphate	11% N 37% P_2O_5	1.41	11.7
	Potassium		
Potassium Ammonium Phosphate	15% N 52% P_2O_5 10% K_2O		
Potassium Ammonium Phosphate	10% N 10% P_2O_5 10% K_2O		
Potassium Ammonium Phosphate	15% N 8% P_2O_5 4% K_2O		

Suspensions have some advantages over solutions.

- Production costs are lower because less materials are used to produce suspensions.
- Higher analysis fertilizers can be produced, especially for grades containing potassium.
- Larger quantities of micronutrients can be added to suspensions than to solutions.

Liquids are excellent carriers of micronutrients and especially suited to application through a trickle irrigation system. When applied through a trickle irrigation system, liquid fertilizers allow for accurate placement of the micronutrient. This increases the fertilizer use efficiency. Plant utilization of the nutrient is more efficient as the nutrients are in a form that is readily available to the roots. Typical grades of clear liquid fertilizers and suspensions that are available from suppliers are shown in Tables 14.3 and 14.4.

Table 14.4 **Typical Grades of Clear Liquid Mixes and Suspensions**

Ratio	Grade	
	Clear Liquid Mix	Suspension
3:1:0	24-8-0	27-9-0
2:1:0	22-11-0	26-13-0
1:1:0	19-19-0	21-21-0
1:1:1	8-8-8	15-15-15
1:2:2	5-10-10	10-20-20
1:3:1	7-21-7	10-30-10
1:3:2	5-15-10	9-27-18
1:3:3	3-9-9	7-21-21

From Western Fertilizer Handbook

Nitrogen Fertigation

Most commercially available forms of nitrogen fertilizer are readily soluble in water and can therefore be used for fertigation purposes. Inert conditioners used as anti-caking agents in some solid nitrogen fertilizers may cause clogging problems if injected into a trickle irrigation system. Homemade fertilizer solutions made by dissolving granular fertilizers should be checked carefully to ensure that all the material is soluble and remains in solution.

A thorough understanding of the available forms of nitrogen is required for proper application of nitrogen fertilizers and solution mixes by fertigation. Many mixes may contain nitrogen in more than one form. Movement of nitrogen nutrients through the soil profile and uptake by the crop will depend upon the forms of N available and the percentage of each form.

Urea (46-0-0) is a highly soluble form of nitrogen fertilizer. In water solutions it acts as a neutral molecule and does not ionize. Urea is often mixed with ammonium nitrate to form a concentrated liquid solution for fertigation. Such mixtures cause only slight ph shifts in the irrigation water. Urea molecules tend to stay in solution and move in the same direction as the irrigation water. However, urea may undergo hydrolysis with an enzyme in the soil and form ammonium. Ammonium is relatively immobile in the soil. Therefore urea placement into the root zone may be achieved with proper irrigation water management. Accurate placement of trickle fertigated urea will depend on the emitter discharge rate, irrigation frequency and the exchange capacity and physical properties of the soil.

Ammonium sulphate (21-0-0) and **calcium nitrate** (15-0-0) are relatively soluble and do not cause a large pH change in irrigation water. Ammonium sulphate, however, is very acidifying once in contact with the soil. In the soil, ammonium (NH_4^+) is nitrified to form nitrate (NO_3^-) plus 4 H^+ ions that increase soil acidity. The nitrification process occurs very quickly in warm moist soils such as under a trickle irrigation emitter.

Anhydrous ammonia (82-0-0) under normal air pressure is a gas but is kept in a liquid form under its own vapour pressure in closed tanks. When dissolved in water anhydrous ammonia forms aqua-ammonia (24-0-0). Anhydrous ammonia is classified as a hazardous material and is not recommended for fertigation. **Aqua-ammonia** when injected into an irrigation system may volatilize gaseous ammonia and result in lower fertilizer efficiency. Ammonia will also increase the pH of the fertilizer solution, increasing the chances of calcium or magnesium precipitates forming. Ammonia fertilizers that are applied through fertigation systems tend to concentrate immediately below the soil surface because ammonia or ammonium are relatively immobile in the soil. In situations where the soil surface temperature is high and alkaline soil conditions persist, ammonium accumulated at the surface may be lost by volatilization. For trickle fertigation systems this loss can be reduced by using a plastic or other mulch system.

Nitrate nitrogen moves freely with the irrigation water and accumulates at the periphery of the wetted soil volume. Proper irrigation system management is required to ensure that nitrates are not leached beyond the plant's active root zone where uptake of the nutrient is no longer possible. Leaching of nitrate nitrogen into groundwater is also a concern. When applying with a sprinkler irrigation system nitrate nitrogen should be applied near the end of the irrigation set to allow for at least one hour of irrigation after injection has completed. This will reduce volatilization losses and provide a better opportunity for incorporating nitrate nitrogen into the soil.

Phosphorus Fertigation

Many forms of phosphorus fertilizers, while soluble in water, react easily with calcium and magnesium in the water to create precipitates that can clog trickle lateral lines and emitters. For example, **treble super phosphate** (0-45-0) changes spontaneously to dicalcium phosphate when in a solution that readily precipitates. This fertilizer is therefore not recommended for fertigation.

Ammonium phosphates, such as ammonium phosphate sulphate (16-20-0), monoammonium phosphate (11-48-0) and diammonium phosphate (16-46-0) are highly soluble in water and are good sources of phosphorus for fertigation. Experience has shown that many phosphate fertilizers may contain a coating that greatly reduces the ease of solubility. Fertilizers without a coating should be selected.

Phosphoric acid (0-55-0) is also a good source of phosphorus for fertigation and has the added benefit of keeping the pH of the injected solution low enough to reduce the potential of dicalcium phosphate or dimagnesium phosphate from forming.

If fertigation of phosphorus is attempted with irrigation water high in calcium and magnesium the water pH should be kept low. The injection of an acid immediately after the injection of phosphorus is one alternative but the best approach is to select a phosphorus source that is compatible with the irrigation water. A precipitation test should be carried out by mixing the fertilizers to be injected with the irrigation water in slightly higher proportions as what will be injected into the irrigation system.

Phosphorus is readily adsorbed and precipitated in most soils and is generally considered immobile when applied topically at normal fertilization rates. However, concentrated phosphorus solutions applied through a trickle irrigation system may move as far as 20 cm horizontally and 30 cm vertically from the emitter drip point.

Convert P_2O_5 to available P, divide P_2O_5 by 2.29.

$P \times 2.29 = P_2O_5$

$P_2O_5 \times 0.43 = P$

$K \times 1.2 = K_2O$

$K_2O \times 0.83 = K$

Potassium Fertigation

Most commercially available potassium fertilizers such as potassium chloride, potassium sulphate and potassium nitrate are all highly soluble in water of any pH value. Heating the stock solution may be required to get potassium sulphate to completely dissolve. Potassium sulphate and potassium nitrate may be preferred over potassium chloride on fruit crops and strawberries that may be chloride sensitive. Potassium is easily applied through most types of fertigation systems.

Potassium is absorbed in the soil by cation exchange similar to ammonium. However, since the potassium ion (K^+) has a lower affinity for the soil colloid surface than does the ammonium ion (NH_4^+) considerable movement of potassium through the soil can be achieved when applied through trickle irrigation systems.

Micronutrients

The major concern of micronutrient fertigation is the high attraction of the cationic micronutrients to the soil particles. Fertigated micronutrient elements may not move far enough to achieve proper placement in the root zone. Foliage spray of micronutrient elements is most often the recommended means of application.

If micronutrients are to be applied by fertigation trickle irrigation systems are the best method. Chelates are very water soluble and a good source of micronutrients for fertigation but may be expensive. Chelates or sulphate salts of micronutrient elements such as iron, zinc, copper and manganese are recommended when applied through a trickle irrigation system. Zinc sulphate may be difficult to dissolve into stock solutions and should therefore be used with caution.

Table 14.5 provides information on inorganic sources of micronutrients.

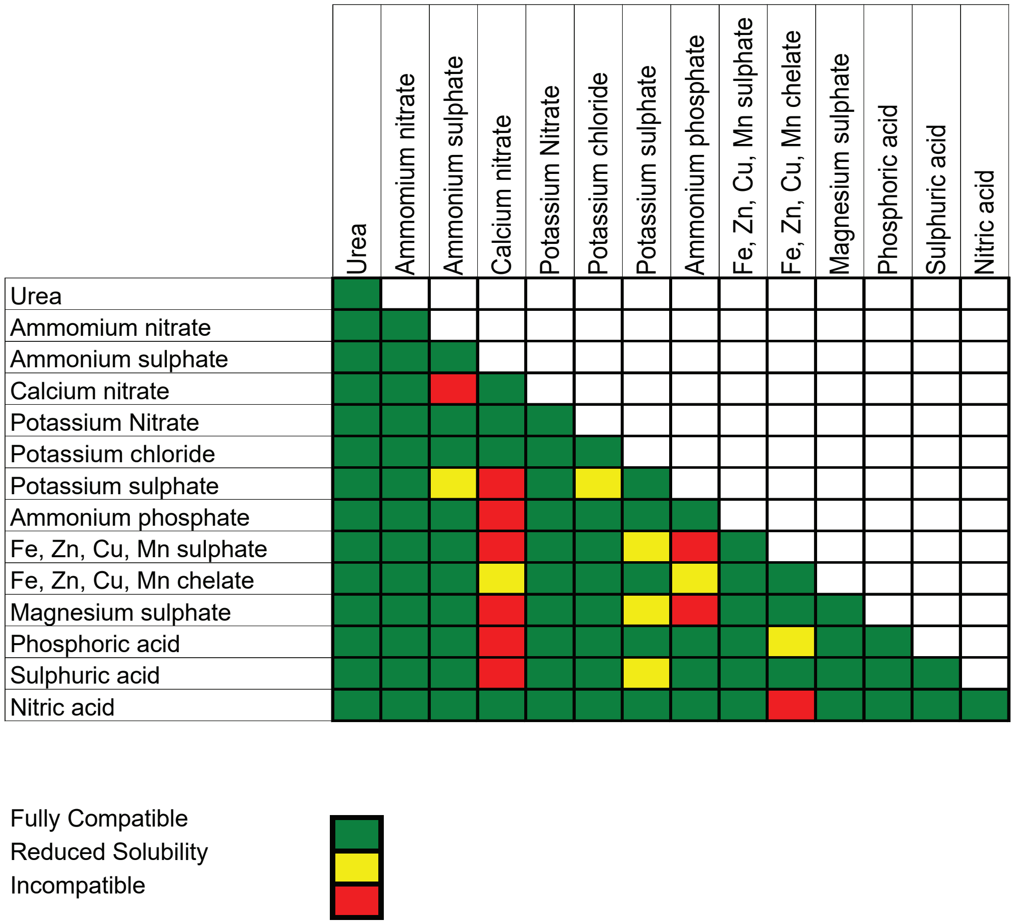
Table 14.5 **Inorganic Sources of Micronutrients**

Material		Element (%)	Water Solubility (g/100g H_2O)	Temp °C
Sources of Boron				
Granular Borax	$Na_2B_4O_7 \cdot 10H_2O$	11.3	2.5	1
Sodium Tetraborate, Anhydrous	$Na_2B_4O_7$	21.5	1.3	0
Solubor®	$Na_2B_8O_{13} \cdot 4H_2O$	20.5	22	30
Ammonium Pentaborate	$NH_4B_5O_8 \cdot 4H_2O$	19.9	7	18
Sources of Copper				
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	25.0	24	0
Cuprous Oxide	Cu_2O	88.8	i*	
Cuptric Oxide	CuO	79.8	i*	
Cuprous Chloride	Cu_2Cl_1	64.2	1.5	25
Cupric Chloride	$CuCl_2$	47.2	71	0
Sources of Iron				
Ferrous Sulfate	$FeSO_4 \cdot 7H_2O$	20.1	33	0
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot 9H_2O$	19.9	440	20
Iron Oxalate	$Fe_2(C_2O_4)_3$	30.0	very soluble	
Ferrous Ammonium Sulfate	$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	14.2	18	0
Ferric Chloride	$FeCl_3$	34.4	74	0
Sources of Zinc				
Zinc Sulfate	$ZnSO_4 \cdot H_2O$	36.4	89	100
Zinc Oxide	ZnO	80.3	i*	
Zinc Carbonate	$ZnCO_3$	52.1	0.001	16
Zinc Chloride	$ZnCl_2$	48.0	432	25
Zinc Oxysulfate	$ZnO \cdot ZnSO_4$	53.8		
Zinc Ammonium Sulfate	$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	16.3	9.6	0
Zinc Nitrate	$Zn(NO_3)_2 \cdot 6H_2O$	22.0	324	20
Sources of Molybdenum				
Sodium Molybdate	$Na_2MoO_4 \cdot H_2O$	39.7	56	0
Ammonium Molybdate	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	54.3	44	25
Molybdic Oxide	MoO_3	66.0	0.11	18
Sources of Manganese				
Manganous Sulfate	$MnSO_4 \cdot 4H_2O$	24.6	105	0
Manganous Carbonate	$MnCO_3$	47.8	0.0065	25
Manganese Oxide	Mn_3O_4	72.0	i*	
Manganese Chloride	$MnCl_2$	43.7	63	0
Manganese Oxide	MnO	77.4		

* – An i denotes insolubility

From Western Fertilizer Handbook

Table 14.6 **Fertilizer Compatibility Chart**



From: Soil and Plant Laboratory Inc., Bellevue, Wa

Some producers may wish to use more than one fertilizer source to obtain the right mix of nutrients that need to be applied. Table 14.6 provides a guide to the compatibility of various types of fertilizers. Do not mix fertilizer combinations that are shown in red and use caution with those shown in yellow. If the fertilizers to be used are not shown check with your fertilizer supplier for additional information.

14.4 Calculating Fertilizer Injection Rates

An injection rate does not need to be calculated if using a weight or volume method of application. Both of these methods inject a batch of fertilizer until it is all gone. An injection rate should be calculated if using an injector pump or an injection system that is set up to automatically inject from one zone to another.

The injection rate depends on the concentration of the liquid to be injected and the quantity of materials to be applied during each irrigation. The following equation may be used for calculating the rate of injection:

Equation 14.1

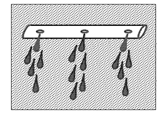
$$I_c = \frac{Qc \times A}{C \times T}$$

Where:

- I_c = Rate of chemical injection (L/min)
- Q_c = Quantity of chemical to be applied per irrigation cycle (kg/ha)
- C = Concentration of injected solution (kg/L)
- A = Area (ha)
- T = Total time of injection (min)

The manual "Chemigation Guidelines for British Columbia" provides alternate methods of calculating injection rates. Example 14.1 provides information on determining a fertilizer mix, tank size and calculating an injection rate.

Example 14.1 Selecting a Fertilizer Source and Calculating an Injector Rate



The linear tape system used in this manual is irrigating a strawberry crop in Abbotsford. An injector pump is to be used to deliver a nutrient mix to the crop. A 1000 liter fertilizer tank is used. The crop nutrient requirements are:

Nitrogen	-	15 kg / ha
Phosphorus	-	60 kg / ha
Potassium	-	55 kg / ha

The final solution must therefore contain a NPK ratio of 15 - 60 - 55.

The nutrients are to be applied to the crop early in the growing season in four equal applications. The injection time is not to exceed 30 min.

The field and irrigation system layout are as follows:

Plant spacing	-	1 ft x 4 ft
Row length	-	400 ft
Number of rows	-	250
Zones	-	8
Flow rate per zone	-	27.3 gpm for six zones and 28.1 for two zones
Operating time	-	2.2 hours during peak conditions
Field size	-	3.7 ha (9.2 acres)
Zone size	-	0.46 ha (1.15 acres)

From Table 14.2 and 14.3 three sources of fertilizer can be selected. If all nutrients are to be applied at one time a fertilizer mix needs to be established. When creating a fertilizer mix, selecting fertilizers that have only one nutrient source makes it easier to get the desired concentrations.

Table 14.6 should be referenced to ensure that all the fertlizers to be used are compatible. The fertilizers selected below are all compatible and can be applied at the same time. The solubility values shown are obtained by interpolating the information given in Table 14.2 for normal operating temperatures. The solubility rates shown in Table 14.2 are not effect for injection into a trickle irrigation system. As explained earlier the recommended solution for drip irrigation is to multiply the solubility rates shown in Table 14.2 by a factor of 10. The solubility rates used for this example are shown below.

	%element	**solubility**	**drip solution** (recommended)
ammonium nitrate (NH_4NO_3)	34% N	120 g / 100 ml	100 g / L
phosphoric acid	52% P_2O_5* 22.7% P	already in solution	
potassium chloride (KCl)	50% K_2O	30 g / 100 ml	30 g /L

* P_2O_5 must be converted into available P by dividing the % P_2O_5 by 2.3.
K_2O must be converted into available K by dividing K_2O by 1.2.

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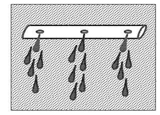
Example 14.1 Selecting a Fertilizer Source and Calculating an Injector Rate *(Continued)*



Since potassium chloride (KCl) has the lowest solubility rate it should be mixed in the tank first. All the other elements must then be added in the correction ratio to obtain the proper mix.

The amount of KCl to add to the tank is:

$$1000 \text{ L tank} \times 30 \text{ g KCl / L} = 30{,}000 \text{ g} = 30 \text{ kg KCl}$$

$$\text{At } 60\% \text{ K} = 30 \times 0.60 = 18 \text{ kg K}$$

The amount of nitrogen and phosphorus to add to the 1000 L tank to keep the original ratio of 15 - 60 -55 will be :

$$\text{For N:} \quad = \text{crop N requirement} \times \frac{\text{actual K to be added}}{\text{crop K requirement}}$$

$$= 15 \times \frac{18}{55} = 4.9 \text{ kg of N}$$

To obtain 4.9 kg of N, the amount of ammonium nitrate required is:

$$\frac{\text{amount of N required}}{\%\text{ element}} = \frac{4.9 \text{ kg}}{0.34} = 14.4 \text{ kg of } NH_4NO_3$$

$$\text{For P:} \quad = \text{crop P requirement} \times \frac{\text{actual K to be added}}{\text{crop K requirement}}$$

$$= 60 \times \frac{18}{55} = 19.6 \text{ kg of P}$$

To obtain 19.6 kg of P from phosphoric acid at a phosphorus percentage of 22.7 % by weight is:

$$\frac{\text{amount of P required}}{\%\text{ element}} = \frac{19.6 \text{ kg}}{0.227} = 86.3 \text{ kg of phosphoric acid}$$

The concentration of N, P and K in the fertilizer solution is:

N = 4.9 kg / 1000 litres	= 0.0049 kg/L	= 0.49%
P = 19.6 kg / 1000 litres	= 0.0196 kg/L	= 1.96%
K = 18 kg/1000 litres	= 0.018 kg/L	= 1.8%
	total	4.25%

This works out to the ratio of 15-60-55 which was initially desired.

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Example 14.1 Selecting a Fertilizer Source and Calculating an Injector Rate *(Continued)*

Once the mix has been established Equation 14.1 can be used to establish the injection rate. Any of the nutrients can be used to calculate the injection rate. Calculating for nitrogen the injection rate is:

Q_c = 15 kg per year in four applications = 3.75 kg /ha per application
A = 0.46 hectares
T = 30 minutes
C = 0.0041 kg/l

$$I_c = \frac{3.75 \text{ Kg/ha x } 0.46 \text{ ha}}{0.0041 \text{ Kg/L x } 30 \text{ min}} = 11.7 \text{ L/min}$$

Checking for potassium:

Q_c = 55 kg per year in four applications = 13.75 kg per application
A = 0.46 hectares
T = 30 minutes
C = 0.018 kg/L

$$I_c = \frac{13.75 \text{ Kg /ha x } 0.46 \text{ ha}}{0.018 \text{ Kg /L x } 30 \text{ min}} = 11.7 \text{ L/min}$$

The same injection rate will result if calculated for phosphorus.

The concentration of the fertilizer solution once injected into the irrigation system is dependent on the original fertilizer mix, the injection rate and the zone flow rate. The fertilizer concentration is the sum of all three nutrients (4.25%). The irrigation system flow rate is 28.1 gpm or 106 Lpm and the injection rate is 11.7 L/min. The injected nutrient concentration is:

$$\text{Fertilizer Solution Concentration} = \frac{4.25\% \text{ solution x } 11.7 \text{ L/min}}{106 \text{ L/min}} = 0.47\ \%$$

The amount of material that will be injected for each zone will be:

11.7 L/min x 30 min = 351 litres.

The 1000 litre tank will therefore only hold enough fertilizer mix for two zones. To be able to fertilize all 8 zones sequentially will require a tank that can hold:

8 zones x 351 liters per zone = 2808 litres.

The amount of fertilizer to use in a tank of this size will then be 2.8 times what was used for the 1000 litre tank.