Agricultural TVET College

Small Scale Irrigation Development

Level III

MODEL TTLM

Learning Guide#02

Unit of Competence: Operate and Process Fertigation Equipment

Module Title: Operating and Processing Fertigation Equipment

LG Code: AGR SSI3M 02 LO1-LO3

TTLM Code: AGR SSI3 TTLM02 1218V_1

Nominal Duration: 45 Hours

Instruction Sheet	Learning guid#02

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Prepare materials and equipment for operation
- Operate the fertigation process
- Shut down fertigation equipment

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- ✓ Calculate and prepare fertigation materials
- ✓ Connect, calibrate and operate the equipment, and
- ✓ Monitor and adjust the delivery of fertilizers
- ✓ Shut down, clean equipment and dispose of waste
- ✓ Use personal protective equipment
- ✓ Identify adverse environmental impacts of fertigation
- ✓ Activities and appropriate remedial action
- ✓ Implement enterprise, OHS and environmental policies and procedures

Learning Activities

1. **Read the specific objectives of this Learning Guide.**
2. **Read the information written in the "Information Sheet"**
3. **Accomplish the "Self-check".**
4. **If you earned a satisfactory evaluation proceed to the next "Information Sheet". However, if your rating is unsatisfactory, see your facilitator for further instructions or go back to Learning Activity.**
5. **Submit your accomplished Self-check. This will form part of your training portfolio.**
6. **Read and Practice "Operation Sheets".**
7. **If you think you are ready proceed to "Job Sheet".**
8. **Request you facilitator to observe your demonstration of the exercises and give you feedback.**

INFORMATION SHEET#1	Prepare materials and equipment for operation

Introduction

Fertigation is the practice of applying fertilizer in a liquid form to a crop via the irrigation system. Using the irrigation system to apply fertilizer reduces the need to use mechanical operations and sometimes eliminate them altogether. When combined with an efficient irrigation system both nutrients and water can be manipulated and managed to obtain the maximum possible yield of marketable production from a given quantity of these inputs.

Fertigation is typically used to address fertilizer deficiency which inhibits plant growth, labour and operational efficiencies. Fertigation has many advantages and disadvantages.

The advantages include:

- fertilizer can be applied directly to the root zone optimizing plant growth
- nutrients can be applied any time during the growing season based on crop need
- highly mobile nutrients such as nitrogen can be carefully managed to ensure rapid crop uptake
- fertilizer can be applied quickly to address any deficiency issues
- minimal crop damage
- tractor operations are reduced, saving fuel, wear and labour
- well-designed injection systems are simple to use and suit automation
- smaller amounts of fertilizer are applied which often results in reduced off site impacts

Disadvantages of fertigation include:

- heavily reliant on the efficiency of the irrigation systems distribution uniformity
- heavily reliant of overall irrigation infrastructure design / layout depending on injection point
- Potential issues during wet weather
- *Requires the addition of safety equipment*. To prevent the possibility of backpressure or back siphonage into a potable water source, approved cross connection control equipment must be installed and proper procedures followed.
- *Requires a change in management techniques*. Personnel in charge of the chemical application must fully understand the calibration of injection equipment and the operation of the injector, irrigation system, check valves and backflow prevention equipment.
- *Portability of equipment*. If a farmer has more than one field, duplication of equipment will be required unless the injection system, solution tank and safety equipment are connected as one unit and can easily be transported from field to field.
- *Timing of application may be limited due to weather*. Sprinkler irrigation systems are susceptible to drift in windy conditions that will affect uniformity and effectiveness of the application. Applications should therefore be limited to good weather conditions.

- *Corrosivity of chemical to irrigation system components*. Chemical solutions may be corrosive to irrigation equipment.
- *Increasing soil acidity***.** The injection of some types of fertilizers into an irrigation system may increase the acidity of the soil. This is especially true for trickle irrigation systems, which concentrate the fertilizer application to a small area.

1.1. Confirming materials and services as available and ready for operation.

The incorporation of fertilizers into the irrigation system demands the following basic requirements:

Equipment may include:

- ✓ Injection pump,
- ✓ injection point
- ✓ chemical holding tank
- ✓ agitator& filter
- ✓ back-flow preventing valve
- ✓ irrigation systems
- ✓ Safety devices (backflow prevention valve, check valve, power safety device, etc)
- ✓ Fertilizers can be in liquid and solid forms.

1.2. Preparing Materials to meet fertigation requirements.

Chemical Selection Criteria

Many factors must be considered when selecting a chemical for injection into an irrigation system. These include:

- **Solubility of chemical.** The chemical must be readily soluble in water and stay in solution during storage and the application process.
- **Desired effect of chemical applied.** The chemical to be applied must achieve the desired effect with this method of application.
- **Effect of chemical on soil.** Addition of some fertilizers may increase the acidity of the soil in the treated area, especially under a trickle irrigated regime.
- **Type of irrigation system.** The uniformity, application efficiency and distribution method of the irrigation system are all important in determining if the chemical to be applied is compatible with the irrigation system.
- **Compatibility of chemical with water source.** Chemicals that react with elements in the water supply after being injected should be avoided.
- **Determination of chemical or nutrient mixes.** Two or more chemicals that are either mixed or applied simultaneously must not react with each other to forma precipitate.
- **State of chemical.** Whether the chemical is in the solid or liquid state will determine handling, injection method and injection rates.

This section will provide some guidance on the selection of various chemicals for injection into an irrigation system.

1. Fertilizers

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 facilities, product stability, and ease of handling, method of injection, cost, and the acidification produced by applying the fertilizer to the soil.

Table1 provides information on the calcium carbonate equivalent for various fertilizers. The amount of calcium carbonate required to neutralize the acidity produced by a given quantity of fertilizer product is the calcium carbonate equivalent. The relative acidifying potentials of fertilizers can be found by comparing the calcium carbonate equivalents.

Based on their primary nutrient content (N, P_2O_5, K_20), fertilizers are given a designation consisting of three numbers. These numbers, called grade, 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 12-12-12grade 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 exceed5%. 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 save 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. Table1 provides the solubility of some fertilizers in water at various temperatures. The solubility of fertilizers may vary greatly with temperature, especially ammonium and potassium nitrates. If the solubility of the fertilizer at ambient air temperatures is known those values should be used. The presence of other substances in the solution may either decrease or increase the solubility.
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 in the same

proportions as when they are mixed in 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 chemical through fertigation should be avoided.

Table1	**Granular Fertilizer Properties**				
Fertilizer	**Molecular Compound**	**%Element**	**Solubility g/100g H_2O**	**Temp °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 Meta phosphate	$Ca(PO_3)_2$		0.001	0	
Calcium Nitrate	$Ca(NO_3)_2.4H_2O$	15.5%N	134 364	0 100	-20
Calcium Sulphate	$CaSO_4.2H_2O$		0.24	0	
Copper Sulphate	$CuSO_4.5H_2O$		32	0	
Diammonium Phosphate	$(NH_4)_2HPO_4$	18%N 20%P	25	0	70
Dicalcium Phosphate	$CaHPO_4.2H_2O$		0.02	0	
Magnesia	MgO		0.0006	0	
Magnesium Sulphate	$MgSO_4.7H_2O$		85	0	
Manganese Sulphate	$MnSO_4.4H_2O$		105	0	
Mono ammonium Phosphate	$NH_4H_2PO_4$	11%N 22%P	43	0	58
Mono calcium 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	$ZnSO_4 . 6H_2O$		70	0	

Liquid Fertilizers

Liquid fertilizers in the past have generally been considered more expensive and offered only lower nutrient concentrations. As the demand for liquid fertilizers has increased, this may no longer be true, with liquid fertilizers offering many intrinsic advantages.

Liquid fertilizers are available as fertilizer solutions and suspensions, both of which may contain multi nutrient 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. Liquid fertilizers offer several advantages over solids.

1. Liquids are especially suited to application through a trickle or sprinkler irrigation system.
2. Liquids are excellent carriers of herbicides.
3. Liquids are excellent carriers of micronutrients. If applied through a trickle irrigation system, liquid fertilizers allow for accurate placement of the micronutrient at the desired location for efficient fertilizer use.
4. Plant utilization of the nutrient is more efficient as the nutrients are in a form that is readily available to the roots. Various fertilizer solutions are shown in table 2.

Table_2: fertilizer

Table2 **Fertilizer Solutions**			
Fertilizer Solution	**%Nutrient**	**Density Kg/Liter**	**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 15%P_2O_5 10%K_2O		
Potassium Ammonium Phosphate	10%N 10%P_2O_5 10%K_20		
Potassium Ammonium Phosphate	15%N 8%P_2O_5 4%K_2O		

Suspensions have some additional advantages over solutions.

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

Take care with suspensions that contain powdered herbicides and insecticides. When injected into an irrigation system these chemicals may come out of solution due to the dilution of the suspension material. Typical grades of clear liquid fertilizers and suspensions that are available from suppliers are shown in table 3.

Table 3 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

A discussion on each type of nutrient follows.

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.

Proper application of nitrogen fertilizers and solution mixes by fertigation requires a thorough understanding of the available forms of nitrogen. 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 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 the soil solution and move in the same direction as the irrigation water. However, urea undergoes hydrolysis with an enzyme in the soil and forms ammonium. Ammonium is relatively immobile in the soil. Therefore urea placement into the root zone can 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 donot cause a large pH change in irrigation water. Ammonium sulphate however is very acidifying once

in contact with the soil. In the soil, $NH4^{+}$ is nitrified to form $NO3^{-}$plus $4H^{+}$ 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). Ammonia fertilizers that are applied through fertigation systems tend to concentrate immediately below the soil surface because ammonia or ammonium is relatively immobile in the soil. In situations where the soil surface temperature is high and alkaline soil conditions persist, ammonium accumulated at the surface is susceptible to losses 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 accumulate at the periphery of the wetted soil volume as subsequent irrigations are applied. 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, allowing 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. Fertigation of this fertilizer is therefore not recommended.

Ammonium phosphates, such as ammonium phosphate sulphate (16-20-0), mono ammonium 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.

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.

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.

Micronutrients

The major concern of micronutrient fertigation is the high affinity 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. Table 4 provides information on inorganic sources of micronutrients.

If micro nutrients are to be applied by fertigation it is recommended that trickle irrigation be used. 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.

Table 4	**Inorganic Sources of Micronutrients**			
Material		Element (%)	**Water Solubility**	**Temp ^{0}C**
Sources of				
Granular Borax	$Na_2B_4O_7 \cdot 1OH_2O$	11.	2.5	1
Sodium Tetraborate, Anhydrous	$Na_2B_4O_7$	21.	1.3	0
Solubor®	$Na_2B_8O_{13} \cdot 4H_2O$	20.	22	30
Ammonium Pentaborate	$NH_4B_5O_8 \cdot 4H_2O$	19.	7	18
Sources of				
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	25.	24	0
Cuprous Oxide	Cu_2O	88.	i	
Cupric Oxide	CuO	79.	i	
Cuprous Chloride	Cu_2Cl_2	64.	1.5	25
Cupric Chloride	$CuCl_2$	47.	71	0
Sources of				
Ferrous Sulfate	$FeSO_4 \cdot 7H_2O$	20.	33	0
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot 9H_2O$	19.	440	20
Iron Oxalate	$Fe_2(C_2O_4)_3$	30.	Very soluble	
Ferrous Ammonium Sulfate	$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	14.	18	0
Ferric Chloride	$FeCl_3$	34.	74	0
Sources of				
Zinc Sulfate	$ZnSO_4 \cdot H_2O$	36.	89	100
Zinc Oxide	ZnO	80.	i	
Zinc Carbonate	$ZnCO_3$	52.	0.00	16
Zinc Chloride	$ZnCl_2$	48.	432	25
Zinc Oxysulfate	$ZnO \cdot ZnSO_4$	53.		
Zinc Ammonium Sulfate	$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	16.	9.6	0
ZincNitrate	$Zn(NO_3)_2 \cdot 6H_2O$	22.	324	20
Sources of				
Sodium Molybdate	$Na_2MoO_4 \cdot H_2O$	39.	56	0
Ammonium Molybdate	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	54.	44	25
Molybdic Oxide	MoO_3	66.	0.11	18
Sources of				
Manganous Sulfate	$MnSO_4 \cdot 4H_2O$	24.	10	0
Manganous Carbonate	$MnCO_3$	47.	0.006	25
Manganese Oxide	Mn_3O_4	72.	i	
Manganese Chloride	$MnCl_2$	43.	6	0
Manganese Oxide	MnO	77.		

2. Chlorine, acid and cleaning agents

Because drip emitters are small, they clog easily. An adequate filtration system is necessary to prevent the introduction of soil particles (sand, silt and clay) and water-borne debris into drip tubes. Additional anti- clogging techniques include acidification, which prevents or removes mineral precipitates, and chlorination, which removes and prevents the growth of bacteria and algae (see table 6).

Table 5. Typical Acid Concentrations

Acid Percentage	Recommended Concentration in Treated Water
Hydrochlori cacid,	0.6%
Phosphoric acid, 85%	0.6%
Nitric acid, 60%	0.6%
Sulphuric acid, 65%	0.6%

Note: If your acid has a different percentage other than the ones listed in Table 5, adjust the percentage accordingly.

Usage: Acid injection is the process of injecting specific concentrations of acid into the irrigation system during regular system operation to lower the pH level in the water. This will dissolve calcium, magnesium carbonates, iron, manganese sulphides and other chemical contaminants. Acid injection can also be used to burn plant roots that have entered the dripper.

In general, acid treatment can be divided to *two types*:

1. **Chemical clogging prevention / treatment** –treatments are typically considered for dissolving minerals and Iron. The pH level should be between 2.5- 5

2. **Root intrusion treatment** –treatments are to be considered for burning roots that have intruded into the dripper passages. The pH level should be between 2 - 2.5. Several heavy treatments may be required, depending on the severity of root intrusion.

Each treatment is designed to lower the pH of the water sufficiently enough to treat the targeted problem, while minimizing the amount of acid to be used, i.e. there's no requirement to lower the pH to a level of 2.0 for the treatment of dissolving calcium carbonates. PH levels can be gradually lowered providing after treatment the drippers are checked and found to be properly cleaned.

Chlorine Treatment for Drip Irrigation Systems

Chlorine is a strong oxidizer. It is useful for the following purposes:
1. Preventing & eliminating the growth of organic slime, iron slime, sulfur slime.
2. Oxidation of elements such as Iron, Sulfur, Manganese, etc.
3. Cleaning organic sedimentation and bacterial slime from irrigation systems.
4. Improving the filtration efficiency, especially sand/media filtration.

Safety

- ❖ Chlorine is effective only on organic matter.
- ❖ Chlorine is ineffective on inorganic matter such as sand, silt, scale etc.

Table:6. Chemical treatment to control clogging of emitting devices

Recognition and Rectification of Problems:			
Sr. No.	**Problem**	**Reasons & identification**	**Control**
1.	**Precipitation of calcium and Magnesium salts**	**Appears as white film on the inside of the lateral /drip tape or in the flow path of drippers associated with increase in pH or decrease in temperature of water.**	**Continuous injection of acid to maintain pH of 6.0 - 6.5 sufficient to prevent formation of precipitation**
2.	**Precipitation of Calcium Carbonate**	**While in solution there will be no problem But as soon as system stops and water evaporates calcium preci-pitates as white crystals around dripper/drip tape orifice and blocks the holes.**	**Continuous injection of acid to reduce pH of water upto 4.0 Repeated treatment for severe blockages.**

3. Precipitation of iron	Changes in temperature and pH cause iron to oxidise to insoluble ferric form causing precipitation. Precipitation forms a red slime mass.	Acid treatment to lower the pH upto or less than 4 and then thorough flushing after 24 hours.
4. Precipitation of Manganese	Manganese can precipitate out as manganese oxide either by chemical or bacterial action and colour of deposit is dark brown or black.	Acid or intermittent Chlorine treatment.
5. Growth of algae within water supply	These need light to grow and hence are found in all surface storage ponds, wells and in slow moving water. Grow quickly and profusely to pose severe problems.	Effective control by adding copper sulphate to water depending upon its concentration which varies from 0.05 to 2 mg/litre.
6. Algae growth within the system	**There are chances of algae growth within filters, on ground mains, submains lateral, drip tape & drippers.**	**Intermittent Chlorine injection**
7. Bacterial precipitation of Sulphur/Sulphides	**Bacteria can produce sulphur if water contains more than 0.1 mg/litre of total sulphides. These bacteria produce White Cottony mass and completely block the emitting device.**	**Intermittent injection of chlorine.**
8. Bacterial precipitation of iron	**With changes in temperature and pH some bacteria cause oxidation of iron to insoluble ferric form causing precipitation. It forms red colour slime and some what gritty slush.**	**Intermittent injection of chlorine.**

To capitalize on fertigation benefits, particular care should be taken in selecting fertilizers and injection equipment as well in the management and maintenance of the system.

Fertilizer preparation

Stock solution preparation: farmers mix solid fertilizers as ammonium sulfate, urea, potassium chloride and nitrate, and liquid phosphoric acid to prepare a “tailor made” stock solution. The stock solution is then injected into the irrigation system, at rates of 2-10 L m3, depending on the desired concentrations of N, P and K. Clear NK, PK and NPK fertilizer solutions with at least 9-10% nutrients (N, P_20_5, K_20) based on cheap solid fertilizers (urea, phosphoric acid and KC1) can be easily prepared on the farm site with limited facilities under “grass roots” field conditions, with minimal mixing.

1.3. Connecting Injection or fertigation equipment

Installation Considerations (Injector)

A permanently installed injector should be plumbed off the main water line (water bypass), which will permit clean water to flow through the irrigation line to purge the line of fertilizer solution or supply water to crop where fertilizer is not needed. A bypass installation also allows easy removal of the unit in case of malfunction or the need for maintenance or replacement.

Consider installation of additional equipment for optimal performance including:

- A 140 or 200-mesh filter is recommended upstream of the injector unit.
- A pressure regulator if in-line water pressure exceeds the maximum allowable for the unit. A one-way check valve may be helpful against water hammer (see "Water Hammer" below).
- A backflow valve to prevent contamination of the irrigation water supply if negative pressure occurs.

Some injectors come with an optional electrical conductivity meter in the water line. This makes it easy to determine whether the injector is functioning properly. Maintenance of the probes on these meters is essential to obtain correct readings. A blending tank may be needed to ensure good mixing of the water and chemicals. Whether you need a blending tank depends on the type of injector and design of the irrigation system.

Water Hammer

Water hammer is kinetic energy (momentum) present in the water that is traveling in one direction. When the water hits a closed valve, such as a solenoid valve, it comes back in the line at four times the original pressure. This puts stress on the whole injector (and on your entire water system), but it is especially destructive to diaphragms. To avoid this, install a simple check valve near your injector.

Verifying an Injector Is Working Properly

The dilution ratio should be known and adjusted as needed (see calibration methods). Soluble fertilizers should be dissolved completely; use hot water if necessary but allow the solution to cool before starting the injector. Before mixing different chemicals in the injector, consult chemical manufacturers to determine the compatibility of the products. Constant agitation is needed when applying wettable powders because they suspend but do not dissolve in water.

Stock Tanks and Mixing Tanks

Stock tanks need to be opaque. The chelating agents in fertilizer (they help to make micronutrients available to the plants) break down if exposed to light. Stock tanks should be covered to prevent algae and/or debris buildup, contamination or evaporation of stock solution. If debris build-up occurs, it may plug the injector intake and cause less than the required amount of stock solution to be taken up. The result will be low fertility and starved crops.

Water-soluble fertilizers tend to accumulate in the bottom of stock tanks, which can result in large differences in fertilizer concentrations. If you are using a large stock tank, make sure the stock solution is mixed well before using it. A good solution is to have a mixing tank equipped with an *agitator*, where you would dissolve the concentrated fertilizer solution (Figure 1).

Caring for an Injector

The intake strainer should be suspended 2 to 4 inches from the bottom of the solution tank to avoid siphoning un dissolved concentrate. Never let the suction tube filter lie on the bottom of the stock tank.

Components of Fertigation equipment

General Principles of Chemigation: Safety Considerations

The irrigation pumping plant and the chemical injection pump should be interlocked so, if the irrigation pumping plant were to stop, the chemical injection pump will also stop. This will prevent chemicals from the supply tank from filling irrigation lines should the irrigation pump stop. With internal combustion engines, the chemical injection pump can be belted to the drive shaft or an accessory engine pulley. Injection pumps driven by electric motors require a separate one-third or one-half horsepower electric motor for the chemical injection pump. Controls for the motors should be electrically interlocked to stop the injection pump motor whenever the irrigation pump stops. This is shown in Figure 1 for electric motors.

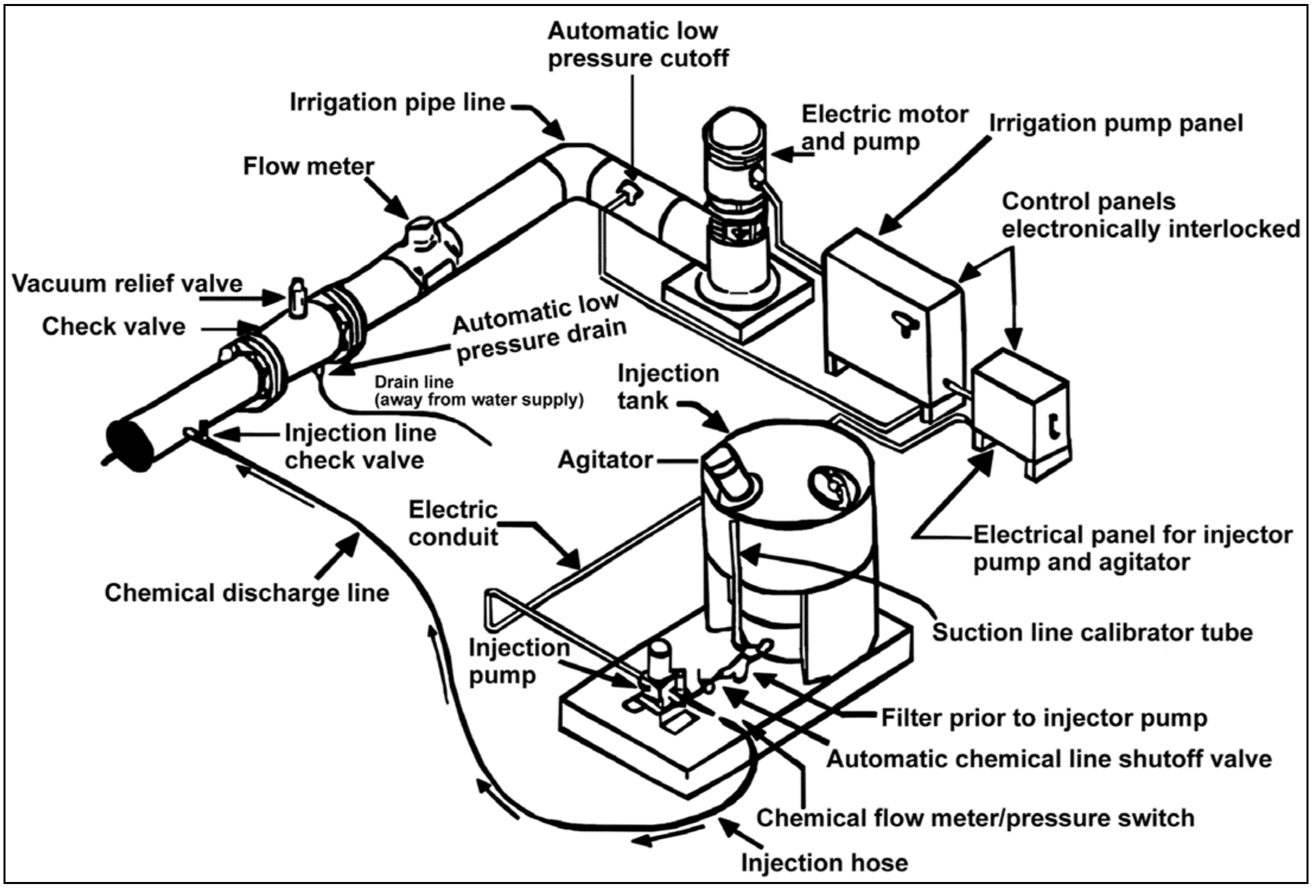


Figure 1: Atypical electrically driven chemigation (fertigation) system

Check and vacuum relief valves (anti-siphon devices) are necessary safety devices. They prevent water or mixtures of water and chemicals from draining or siphoning back into the water source. Both valves must be located between the irrigation pump discharge and the point where chemicals are injected into the irrigation pipeline (Figure 1).

Vacuum relief valve. The vacuum relief valve must be located on top of the irrigation pipeline between the irrigation pump and the irrigation pipeline check valve (figure 1) to prevent a vacuum that could cause siphoning when the water flow stops.

Low pressure drain. The low pressure drain must be installed on the bottom of the horizontal pipe between the irrigation pump and the irrigation pipeline check valve. The drain must, in all instances, be located on the irrigation pipeline before the point of chemical injection.
There should be a low pressure drain and vacuum breaker between the injection line and the water source to prevent seepage back into the water system when nothing is running. The low pressure drain should be discharged at least 20 feet from any water supply source and protected from draining toward it.

Chemical injection line check valve. A check valve must be installed in the chemical injection line between the chemical injection pump and the chemical injection port on the irrigation pipeline. Its purpose is twofold:

1) To prevent gravity flow from the chemical supply tank into the irrigation pipeline, and

2) To prevent irrigation system water from flowing into the chemical supply tank causing an overflow.

Simultaneous interlock (control panels electronically interlocked). Enterprise regulations require the irrigation pumping plant and the chemical injection pump to be interlocked so that if the pumping plant stops, the injection pump also will stop. This will prevent pumping chemicals into the irrigation pipeline after the irrigation pump stops.

A check valve should be installed in the chemical injection line to prevent the back flow of water from the irrigation system into the chemical supply tank. If the injection pump stops and there is no check valve, irrigation water can flow through the injection line into the chemical supply tank. Subsequently, the tank may overflow and cause a chemical spill around the water source. Chemicals from such spills can contaminate ground and surface water.

An additional safety item is a small, normally **closed solenoid valve** to be electrically interlocked with the engine or motor that drives the injection pump. This solenoid valve provides a positive shutoff in the chemical injection line, which stops chemical or water flow in either direction if the injector pump stops.

For automated control, a pressure switch should be electrically interlocked with the safety panel on the irrigation system. This switch will automatically shut down the irrigation system and the injection pump if pressure is lost in the injection discharge line. Usually, loss of pressure in injection lines occurs when the chemical tank is pumped dry.

Chemical Supply Tank .To avoid potential reactions with chemicals placed in it, the chemical supply tank should be constructed of a corrosion resistant material such as stainless steel or sunlight resistant plastic.

Agitator in the chemical tank is required for mixing. Hydraulic agitation may be sufficient for some soluble chemicals, while mechanical agitation may be necessary for other types of chemicals.

A **strainer or Filter** should be installed between the chemical supply tank and the injection pump to prevent clogging of the injection pump, check valve, or other equipment.

Injection Pumps

Injection pumps .inject chemical into the irrigation water at a predetermined rate .Two basic types of injection pumps — the **Venturi** (Figure 2) and the **metering pump** (Figure 3) are commonly used for injecting fertilizer and other chemicals into drip-irrigation systems. Field setups for both types should have an adjustable injection rate. Any components that will be in contact with fertilizer, chlorine or acid should be resistant to corrosion.

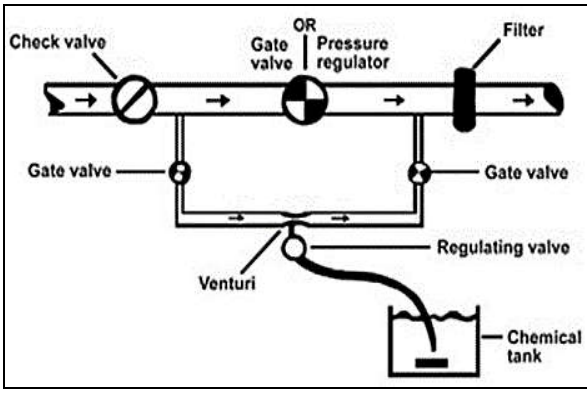


Figure 2. Venturi chemical injector.

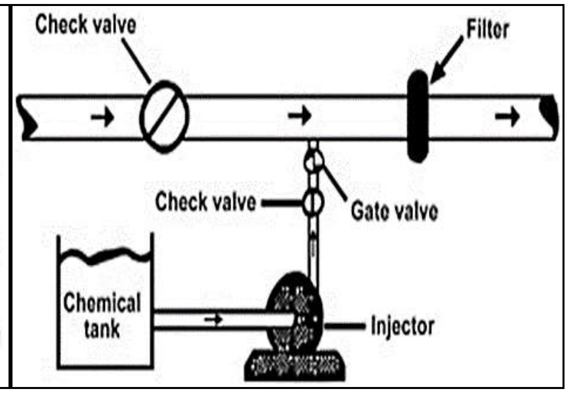


Figure 3. Chemical metering pump

Venturi

The Venturi system creates a pressure differential that forms a vacuum. As water flows through the tapered Venturi orifice, a rapid change in velocity occurs. This velocity change creates a reduced pressure (vacuum), which draws (pulls) the liquid to be injected into the system. Since the injection rate will vary with the pressure differential across the Venturi, a precise regulating valve and a flow meter are recommended for calibrating the system.

Metering Pump

Positive displacement metering pumps are often used to inject chemical solutions into drip irrigation systems. Portable positive displacement pumps can be moved from field to field. Metering pumps may be powered by small electric motors or by hydraulic drive systems. Hydraulic drive systems use the water pressure in the system to power the pump. In the past, injection rates of positive displacement pumps were adjusted by changing the length of the piston stroke. However, injection rates of some of the more recent models can be adjusted with a variable frequency drive. This drive varies the speed of the injection pump with the flow rate of the irrigation system.

Calibration Tube

A calibration tube should be located in the chemical line between the chemical supply tank and the injection pump. It is used to measure output of the injection unit during calibration. It should be transparent for ease in viewing the liquid level, resistant to breakage, ultraviolet light (UV) stabilized (sunlight resistant), and graduated in units of volume (pints, ounces, milliliters, etc.).

Injection Point Location

The injection point must be between the check valve and the filter. To allow enough time for the fertilizer solution to mix uniformly, use at least 25 feet of line between the injection point and the filter system. It should also pass through at least two 90-degree turns to ensure enough time for thorough mixing and for any precipitant to come out in front of the filter. This gives more uniformity to the fertilizer each plant receives and decreases the danger of a precipitant's plugging the system.

The system should be allowed to fill and come up to full pressure before injection begins. Following injection, the system should be operated to flush the fertilizer from the lines. Leaving residual fertilizer in the line may encourage clogging from chemical precipitates or organic sources such as bacterial slimes.

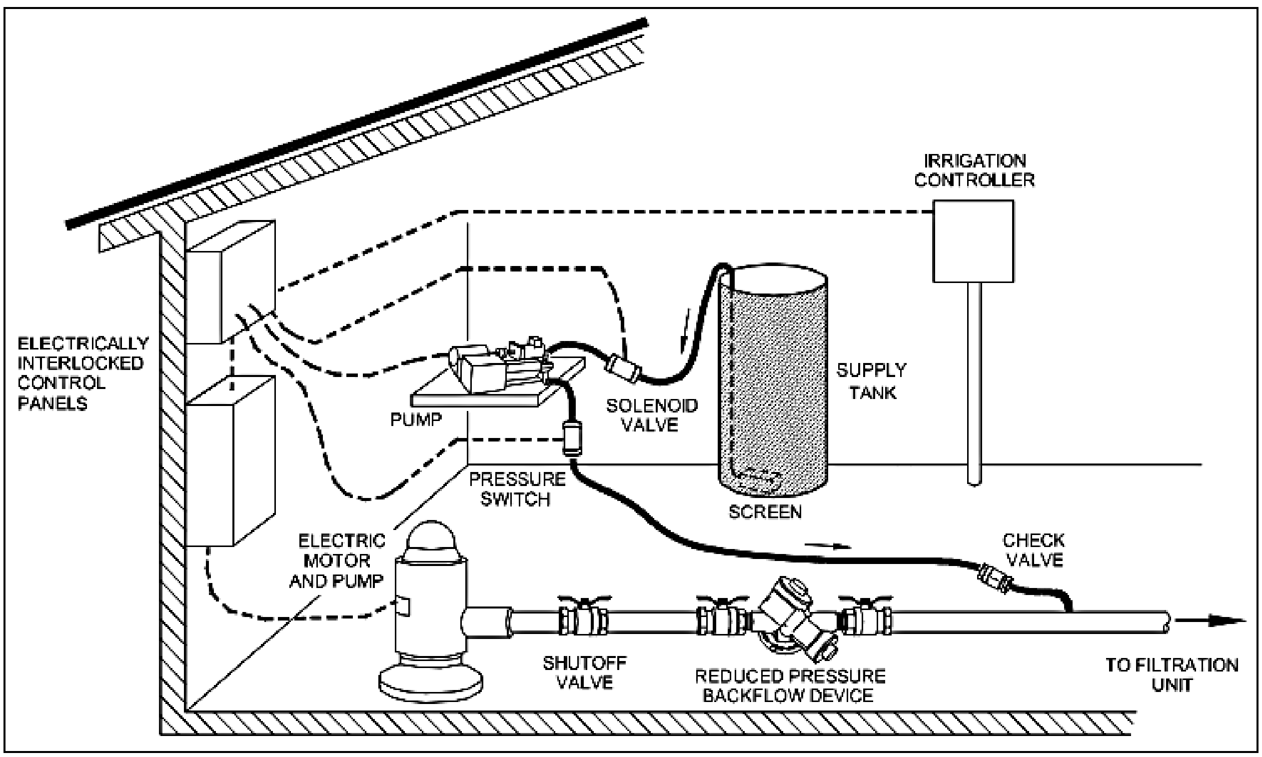


Figure 4. Injection system safety features

1.4. Calculating Fertilizer concentration and mixing the solution thoroughly

Determining a Method of Calculating Injection Rates

The optimal utilization of a fertigation system does not only contain the use of dependable equipment, but also the accurate calculation of the correct injection rate. The calibration of the injectors after installation must also be done to ensure that the injection pump complies with the manufacturer's specifications under field conditions.

There are four different methods that can be used to determine how much chemical must be added by the injection system. Usually it is not practical to adjust fertigation rates by adjusting the injection rate. With venturi, for instance, the injection rate will be fixed by the operating pressures of the irrigation system. With variable speed metering pumps, it will be necessary to reset injection rates or solution concentrations to adjust for unequal sized zones. It is therefore more practical to use alternative procedures for controlling application rates. Four different methods could be used depending on the type of chemical, injector, type of irrigation system, zone size and number of zones.

1. **Weight Method**: Weigh out the desired weight of material to be applied, dissolve in a convenient amount of water, and inject until it has all been applied. Knowledge of the injection rate will be required to ensure that concentration in the irrigation lines is not too strong and that the time for injection is not too long.

2. **Volume Method**: Similar to the weight method except that concentration of the liquid solution must be known to calculate how much volume to apply.

3. **Injection Rate Method**

4. **Injection Time Method**: The time required to inject the amount of chemical is calculated from the injection rate and solution concentration using the same equation as for the injection rate method

Calibrating an injection pumping system

Calibration of a fertigation system involves the following basic steps.

1. Determine the area to be treated or the number of plants to be treated with a trickle irrigation system.
2. Determine the amount of chemical to be applied per hectare or per plant.
3. Calculate the total amount of chemical to be applied.
4. Determine the length of injection time in hours. Factors that will influence this are the length of the irrigation set time, irrigation system application rate, transit time from the injection point to the target area and the amount of chemical to be applied.
5. Select the chemical composition to be used and mixture concentration.

6. Set the injection flow rate on the injector.

The injection rate may be predetermined by the capacity of the injector or the flow rate of the irrigation system. The desired injection rate can also be calculated by using the following formula if all of the parameters are known.

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

Where: **Ic** = Chemical injection rate (L/min)

Q_C = Quantity of chemical to be applied to target area (kg/ha)

A = area (ha)

C = concentration of injected solution (kg/L)

T = injection duration (min)

The method of calibrating chemigation systems using different irrigation systems and chemicals is best exemplified through the following examples. Consideration must be given to batch vs. continuous injection and the target area effectively covered by the irrigation system.

Batch chemigation examples

Irrigation systems such as wheel lines, hand lines, solid set sprinklers and trickle operate in a batch mode. These systems irrigate a block of land at a constant rate for a fixed period. Batch chemicals can therefore be mixed and applied to these blocks during irrigation.

The amount to be applied is easily determined for a batch application process. The timing of application of a batch system is most critical if the chemical is to be applied to a specific area of the plant's root zone. This is determined by the type of chemical used and the duration of application.

The amount of water applied by the irrigation system must be stored within the plant's root zone. Any moisture that is applied that exceeds the holding capacity of the soil will cause leaching beyond the plant's rooting depth. The specific depth in the soil to which chemicals are applied can be determined from the application rate of the irrigation system, the duration of irrigation, soil texture and soil moisture content before the chemigation is applied.

Example 1. Solid Set Sprinkler-Fertilizer Application

Solid set systems irrigate blocks of land controlled by a single valve. The following example provides the calibration sequence for a solid set sprinkler system.

The irrigation system has the following particulars:

- 5/32" x3/32" nozzle operating at 45psi
- 1 gpm flow rate per sprinkler

- 90ft wetted diameter
- 45ft x55ft spacing
- 20 sprinklers operating in the zone
- Zone flow rate is 130gpm
- Irrigation set time is 12hours

Calcium nitrate fertilizer is to be used to apply 50 kg of nitrogen per hectare to a mature orchard crop on a sandy loam soil. The moisture content of the soil is at 25% of the Available Water Storage Capacity is 11in/in. The nitrogen is to be applied to a depth of 300mm (12in).

1. Area to be treated.

For a sprinkler system the area to be treated is calculated by using the sprinkler spacing and number of sprinklers. Water application will occur outside this calculated area but it is expected that the same amount will be returned to the target area from the next set.

$$\text{Treated area} = \frac{\text{no. of sprinklers X sprinkler spacing}}{43{,}560\text{ft}^2/\text{ acre}}$$

$$\text{Treated area} = \frac{20x45x55}{43{,}560}$$

$$= 1.14\text{acres}$$

$$= 0.46\text{hectares}$$

2. Amount of chemical to be applied per hectare

From Table 1the following information can be obtained on Calcium Nitrate.

- 15.5%N
- Solubility-180 g / 100 g H_2O, i.e. 1.8kg/Lit (this value is interpreted from the table using a temperature of 20^oC
- $CaCO_3$ equivalency is -20

Calcium nitrate will not acidify the soil as a negative amount of calcium carbonate is required to neutralize the acidic effect.

To apply 50 kg of nitrogen per hectare the weight of Calcium Nitrate fertilizer will be:

$$\mathbf{Qc} = \frac{\text{desired amount of N / Ha}}{\text{percentage N in fertilizer}}$$

$$= \frac{50}{0.155}$$

$$= 323\text{kg of calcium nitrate / hectare}$$

3. **Total amount of chemical to be applied**

Amount applied = rate per hectare X no. of hectares
= 323kg/ha x0.46hectares
= 149kg

At solubility rate of 1.8kg/L the minimum volume of solution will be:

$$\textbf{Solution volume} = \frac{\text{total amount to be applied}}{\text{Solubility rate}} = \frac{149\text{kg}}{1.8\text{kg/L}} = 83\text{L}$$

A tank capable of 83 liters of chemical storage is required if calcium nitrate is to be used as the nitrogen source. The nutrient mixture concentration can be diluted if the solubility of the calcium nitrate is reduced due to fertilizer coatings. A larger tank will then be required.

4. **Length of injection time**

An injection time of 1hour is selected to ensure that the chemical is applied as uniformly as possible. The chemical is to be applied during part of the normal 12hour set time so there is ample time to inject the product. Step6 shows the methodology for calculating when the chemical should be applied if a specified depth is desired.

5. Injection Rate (Ic): $$Ic = \frac{Qc \times A}{C \times T}$$

Where

Ic	=	chemical injection rate (L/min)
Qc	=	323kg/ha
A	=	0.46ha
C	=	1.8kg/L
T	=	60min

$$Ic = \frac{323 \times 0.46}{1.8 \times 60}$$

$$= 1.38\text{L/min}$$

The maximum concentration of injected solution in the irrigation lines selected for this example is 1%. The irrigation system flow rate is 130 gpm or490 L/min.

The concentration of solution in the irrigation line is:

$$\text{Solution concentration} = \frac{\text{injection rate}}{\text{System flow rate}} = \frac{1.38}{490} = 0.0028 \text{ or approximately } 0.3\%.$$

For this example, a 1.38 L/min injection rate is well within the 1% fertilizer concentration limit that was set.

6. Depth of Penetration

$$\text{Application rate} = \frac{96.3 \times 1\text{gpm}}{\text{Sprinkler spacing}}$$

$$= \frac{96.3\text{x}6.5}{45\text{ft x}55\text{ft}} = 0.25 \text{ in/hr}$$

Total application = application rate X time

= 0.25in/hr x12hrs

= 3in applied

Depth of water penetration = total application x(25% moisture content on sandy loam)

= 3in x11in/ inch applied

= 33inches

Desired depth of chemical is 12inches

$$\text{Amount of irrigation required} = \frac{\text{12inches x12hrs.}}{\text{33inches}}$$

= 4.4 hours of irrigation required after injection begins.

The chemical injection must be started 7.6 hours after the irrigation set begins and be completed one hour later. The chemical will then have 4.4hoursto infiltrate into the soil to a depth of12inches during a 12hour irrigation set.

Example 2. Trickle Irrigation System - Granular Fertilizer

Trickle systems irrigate the plant's roots directly and should be designed to irrigate blocks of the same maturity, crop and soil type. For this example, a first year planting of tree fruits requires 15g of phosphorous to be applied.

The following parameters are used for this example:

- the orchard is high density with plant spacing of 5 ft and rows spaced 12 ft. apart
- the rows are 250 ft. long (50 plants per row)
- one zone irrigates 20 rows at one time
- each tree is supplied by two 2 L/hr. emitters

- a normal irrigation is approximately 9 hours of operation per day during peak conditions for a mature crop. For a first year crop the operating time is estimated to be 2 hours per day.

The grower wishes to apply 15 g of actual phosphorus to each plant over the growing season, in 8 equal applications one week apart. **Mono ammonium phosphate** will be used as the phosphorus source.

1. Number of plants to be treated

Number of plants = plants per row x number of rows
= 50 x 20
= 1000

2. Amount of chemical to be applied per application

From Table1the following information can be obtained on mono ammonium phosphate.

- 11%N
- 22% actual P (Note phosphorus fertilizers often provide the amount of phosphorus as P_2O_5. To convert from P_2O_5 to actual P, divide P_20_5 by 2.3)
- solubility =43g/ 100g H_2O or 0.43kg/L
- $CaCO_3$ equivalency is 58

Mono ammonium phosphate has an acidifying effect on the soil. Liming may be required if this fertilizer is used extensively.

The amount of actual fertilizer to be applied per application is:

$$\text{Amount applied} = \frac{\text{amount per tree X no. of trees}}{\text{no. of applications X \% P in fertilizer}}$$

$$= \frac{15\text{g/tree X1000 trees}}{8\text{x}0.22} = 8522\text{g} = 8.5\text{kg}$$

3. Volume of solution

The minimum volume of solution required to dissolve this amount of fertilizer will be:

$$= \frac{\text{total amount to be applied}}{\text{Solubility rate}} = \frac{8.5\text{L}}{0.43\text{kg/L}} = 19.8\text{L}$$

The minimum storage tank size required is therefore 20L. In this example 30 L is used to dissolve the 8.5 kg of fertilizer. *The solution concentration is therefore 8.5kg/ 30L= 0.28kg/L.*

4. Injection Rate

The entire chemical is to be injected in 1hour. The injection rate is therefore 30L/hr. The

maximum concentration of injected solution into the irrigation lines is selected to be 1%.
The flow rate of this zone is =1000trees x 4L/hr/tree = 4000L/hr

$$\text{Concentration of chemical in the irrigation lines is} = \frac{\text{injection rate}}{\text{System flow rate}} = \frac{30L/hr}{4000L/hr}$$

= 0.0075 or 0.75 % .This injection rate is therefore acceptable.

The amount of nitrogen applied to each tree can also be calculated. The N concentration in the fertilizer is 11 % vs. 22 % for phosphorus. A total of 7.5 gm of N is therefore applied to the crop over the 8 applications.

Example 3. Line Source Trickle System – Liquid Fertilizer

A line source trickle system is used to irrigate a strawberry crop. A liquid fertilizer solution is to be used to apply nitrogen and phosphorus to the crop. The following parameters exist for the irrigation system.

- the strawberries are spaced 1ft apart with rows4ft apart
- row lengths are 300ft (300plants per row)
- 12"x60"Bi-wall operating at 12psi is used to irrigate the crop
- flow rate is 1.55gpmper 300ft row
- there are 25rowsirrigated by one zone
- a normal operating time for each zone is approximately1hour

The grower wishes to apply a total of 1gm of N and 1.5gm of P to each plant in five equal weekly applications at the beginning of the season. An ammonium polyphosphate solution is to be used.

1. Number of plants to be treated

Number of plants = plants per row X number of rows in one zone
= 300 x 25
= 7500 plants

2. Amount of chemical to be applied per application

In this case a nutrient solution should be selected that closely matches the nutrient application desired. From Table 2 the following information can be obtained on ammonium phosphate solutions: Select an ammonium polyphosphate solution of 10-34-0.

- 10%N

- ➢ $34\% P_2O_5$ To convert to actual P divide by 2.3
- ➢ 14.8%P
- ➢ Density is 1.37kg/L or 1370g/L

The amount of fertilizer required to fulfill the minimum nutrient requirement is:

$$\text{Amount of fertilizer} = \frac{\text{Amount per plant X number of plant}}{\text{no. of applications X density of solution X \% nutrient}}$$

$$\text{For N} = \frac{1g/L \times 7{,}500}{5 \times 1370g/L \times 0.10}$$

$$= 10.95\text{liters}$$

$$\text{For P} = \frac{1.5g \times 7{,}500}{5 \times 1370g/L \times 0.148}$$

$$= 11.1\text{liters}$$

Approximately11liters of 10-34-0 solution are required per application.

3. Injection rate

The fertilizer is to be applied during 20 minute duration halfway into the irrigation cycle to allow for proper pressurization of the system and adequate flush time after injection has been completed. The injection rate is therefore:

$$\frac{11\text{litres} \times 60 \text{ minutes}}{20 \text{ minutes /hour}} = 33\text{litres/hr}$$

The maximum concentration of injected solution in the irrigation lines should not exceed 1%.
The flow rate of the zone is:

1.55gpm/ lateral x 25laterals = 38.75gpm (1 U.S. gal = 3.785litres) or

38.75 X (60/hr) X 3.785L = 8800L/hr

The concentration of chemical in the irrigation line is:

$$= \frac{\text{injection rate}}{\text{System flow rate}}$$

$$= \frac{33L/hr}{8800L/hr} = 0.003754 \text{ or } 0.375\%.$$ This injection rate is therefore acceptable.

1.5. Setting Equipment to meet fertigation requirements.

Calibrating the Injection Pump

Chemigation should never be attempted without accurate calibration. Manufacturers' suggested settings are helpful guides. However, to ensure that recommended amounts are being applied at the desired concentrations, calibrate the injection pump on-site.

The objective of calibrating the injection pump is to adjust the pump injection rate to the desired injection rate. The pump injection rate is determined by measuring the volume of solution pumped through the injection pump (injected volume) during a specific duration of time (usually 60 to 120 seconds).

The injected volume can be determined by any of the following methods:

Method 1- Using a graduated cylinder, measures a selected volume of the solution to be injected. The selected volume should be of sufficient quantity to allow injection for several minutes. Place this known volume into a container connected to the intake line of the injection pump. With the system operating and fully charged, activate the injection pump and determine the number of seconds required for this known volume to be injected.

Method 2 - This method is similar to the above method. The primary difference is, in method 2, only a portion of the measured chemical solution is injected. Using a graduated cylinder, measure a selected volume of the solution to be injected. This selected volume should be of sufficient quantity to allow injection for several minutes. Place this known volume into a container connected to the intake line of the injection pump. With the system operating and fully charged, activate the injection pump for a specific duration of time. This injection period should be for several minutes. However, it should be short enough so that only a portion of the solution is injected. At the completion of the injection period, measure the volume of solution left in the container. The volume of injected solution is determined by subtracting the amount remaining after injection from the original volume.

Method 3- In this method, the solution pumped through the injection pump during a given period of time is collected and measured. With the system operating and fully charged, activate the injection pump for a specific time (2 to 5 minutes). Divert the output line from the injection pump into a container. A pressure regulating device should be installed on the output line to simulate system back pressure. Measure the output with a graduated cylinder to determine the volume of chemical injected.

Self-Check 1	Written Test

Name: __________________________ Date: ________________

Directions: Answer all the questions listed below.

1. What is fertigation? (2 points)

2. Describe methods of selection of fertilizer. (4points)

3. What is the difference between solid and liquid fertilizers? (2points)

4. List and describe components of fertigation equipment. (5 points)

4. Describe safety devices of irrigation and injection systems? (3points)

5. What are the cleaning agents mostly used in fertigation? (3points)

6. Describe calibration of injector equipment? (4pts)

7. Why the power system of irrigation and injection equipment is electronically interlocked? (2pts)

Note: satisfactory Rating-25 and above pts. Unsatisfactory Rating-below 25 pts.

You can ask your teacher for the copy of the correct answers

INFORMATION SHEET#2	Operate the fertigation process

2.1. Implementing Start up sequence

Among the most frequent causes of chemical spills could be hose ruptures, hose clamp failures, and leaking connections –all defects that an adequate pre-operation inspection should detect. To help ensure safe fertigation events, equipment must be maintained properly. All hoses, clamps and fittings must be in good repair. It is strongly recommended that all chemical injection line hoses and clamps be replaced annually. Inspect them for deterioration before each fertigation operation.

All components that are in contact with chemicals, from the supply tank to the point of injection on the irrigation pipeline, should be constructed of chemically resistant materials.

Before fertigation, inspect equipment to be certain that the following items are functioning properly:

- The irrigation system main pipe line check valve and vacuum relief valve;
- The low pressure drain (also check drain hose for proper connection and breakage and ensure that it is draining to the desired location);
- The chemical injection line check valve;
- The irrigation system and pumping plant main control panel and the chemical injection pump safety interlock;
- The injection system including the in-line strainer;
- The irrigation pumps and power source.

2.2. Operating and monitoring Fertigation process

Injection pumps must be accurately calibrated by properly adjusting the injection rate. Ideally, an injection pump should be capable of being adjusted to the desired injection rate. However, it is not always possible to obtain an injector pump that accurately injects at low chemical injection rates (commonly encountered with small drip systems). If the injector is to also inject fertilizer, it will need sufficient capacity for injecting fertilizer. Injection rates for fertilizers are usually much higher than injection rates for chemicals such as liquid chlorine or acid.

In some situations, it may not be possible to lower the injection rate enough to inject concentrated solutions at the desired rate. This problem can usually be overcome by adding a precise amount of water to dilute the concentration of the active ingredient in the solution

Monitoring is the process of controlling a given system by continuous inspection or observation and recording the results and reporting the results for concerned body. It is a key factor that determines the success or failure of a given fertigation equipments during operation times.

How to Monitor Fertigation

Fertigation is a powerful cultural tool but must be carefully monitored. There are two way to check your fertigation program: electrical conductivity (EC) and foliar nutrient levels. The best way to determine if your fertilizer injector is working properly is to monitor the EC of the various fertilizer solutions. EC is a measure of the salinity (total salt level) of a solution and therefore gives an indication of the dissolved fertilizer salts. An EC meter measures the electrical charge carried by the ions that are dissolved in a solution — the more concentrated the ions, the higher the reading. By checking the EC at each step in the process looks like the Figure below, you can be sure that your injector is functioning properly.

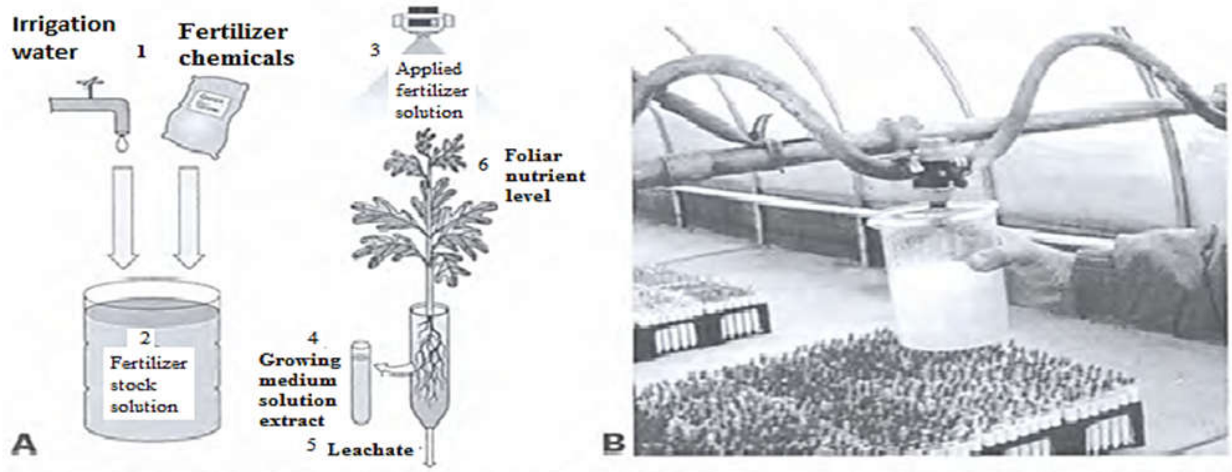


Figure 5 - Checking the electrical conductivity at each stage of the fertigation process (1-5) ensures that the injector if working properly and regular foliar analysis (6) proves that your crop is receiving the proper levels of all mineral nutrients (A). The most critical check is the applied fertilizer solution that goes on your crop (B).

1. Irrigation water - The base EC of the irrigation water should be monitored monthly, or until you are certain that it does not vary significantly during the season.

2. Fertilizer stock solutions -The efficiency of the fertilizer injector can be checked by making an "applied strength" dilution of the fertilizer stock solution and measuring the EC level. For a 1:100 injector, add one part of stock solution to 100 parts of irrigation water. The EC reading of the diluted fertilizer solution should be approximately the same (within 10%) as the EC of the fertigation solution that is applied to your crop.

3. Applied fertilizer solution - The applied fertilizer solution is by far the most important of the fertilization checks because this solution actually contacts the seedling foliage and enters the root zone. Even if you don't check anything else, be sure to do this test regularly. The applied solution is-collected directly from the irrigation nozzle (Figure 5B) and the EC reading should be approximately the sum of the base salinity of the irrigation water plus the salts added by the fertilizer stock solution. Send a sample of this solution to a testing laboratory and check the levels of the mineral nutrients against your calculated values.

4. Growing medium extract -Samples of the irrigation water and the applied fertilizer solution can be collected directly, but liquid samples must be extracted from the growing medium. The amount of growing medium solution is relatively small and is strongly absorbed, and so special sampling techniques must be used to collect enough solution to measure.

5. ***Leachate*** - The final check involves taking EC readings on the "leachate" solution that drains from the bottom of the containers. Leachate can be obtained by taping a test-tube or other container to the drain hole of the container or by placing a tray under a block of containers during fertigation. If the EC of the leachate significantly exceeds the EC of the applied fertilizer solution, then excess salinity is building up in the growing medium and proper leaching is not occurring.

6. Foliar nutrient levels - While EC readings can reveal when overall problems with your fertigation system, the only comprehensive test is to chemically analyze the foliage of your crop and determine its nutrient status. The mineral nutrient concentration of the seedling foliage reflects the actual uptake of all the mineral nutrients.

2.3. Monitoring Fertigation equipment to ensure no adverse environmental impact caused by faulty operation

Drift and runoff are the two leading causes of chemical losses from chemigation systems. Environmental conditions during application, sprinkler types, type of chemical being applied and climatic conditions after application all affect the magnitude of chemical losses.

Water discharged from a sprinkler nozzle under pressure emerges as a fine spray. Part of the spray is evaporated within the wetted area, intercepted by vegetation and soil or carried away by wind outside the intended target area. Wind drift can be a potentially hazardous situation. Chemigation should not be carried out if wind conditions are strong enough to cause significant drifting to non-target areas.

Runoff depends not only on the irrigation system application rate and soil infiltration rate but is also influenced by factors such as field slope, surface vegetation, crop cover and soil surface residue. Irrigation systems applying chemicals must be designed and operated to prevent any runoff from occurring.

The injection system could shut off unexpectedly while the irrigation system continues to operate. Overflow of the tank could occur resulting in chemicals being spilled on to the ground. The chemical injection line must contain a functional, automatic quick closing check valve to prevent the flow of water from the irrigation system back through the injector into the chemical storage tank.

During any chemical application, periodically monitor the irrigation system and chemical injection equipment to be certain that both are operating properly. Check the wind speed and direction periodically to ensure that wind drift will not transport chemical to a non target area.

Application must be done under minimal wind conditions to allow good distribution, prevent drift and minimize evaporation of the product. Wind conditions must be less than 2 km/hr during the entire time of application to prevent drift off the target area.

Avoid Non-target Application

Ground, *Surface Water:* Certain conditions may preclude chemigating. For example, if there is an uncapped abandoned well, flowing water in a creek channel or a wetland within the target area, chemigation would not be a legal option. Any person, who contaminates groundwater or applies an agricultural chemical to permanent or semi-permanent surface water areas, violates the regulation and rules of environmental protection and its development.

Chemical hazard when not handled properly, nutrients, acids and chemicals may cause serious injury or even death. They may also damage the crop, the soil, the environment and the irrigation system. Proper handling of nutrients, acids and chemicals is the responsibility of the grower. Always observe the nutrient/acid/chemical manufacturer's instructions and the regulations issued to protect adverse environmental impact of the surrounding area.

2.4. Implementing Corrections to the process and equipment adjustments as necessary

The following application tips are provided with the objective of preventing contamination of nearby water sources, and to ensure good OH&S and handling practices.

- Maintain a neat storage, mixing and injection area. This promotes safe handling, and facilitates early recognition and clean-up of any spills and leaks.
- Prevent drainage from the mixing area into streams, dams or bores.
- Prevent back-flow from the irrigation lines into the water supply. This is more likely to occur where suction systems, on the inlet side of the pump, are used to introduce fertilizer solutions.
- Allow excess water to re-enter reticulated water supplies for use on other irrigated fields where the same crops are grown. Livestock should be denied access to tail-water to avoid any risk of urea or nitrate poisoning.
- Prepare fertilizer solutions as close as possible to the time of use. Do not allow to stand for an extended period of time e.g. overnight. This can help minimize precipitation and settling in mixing tanks in some instances.

- Inject fertilizer solutions upstream of filters, so that insoluble contaminants are screened out.
- Flush injectors and lines after use, to minimize corrosion and scale formation, and extend the life of gaskets.

Self-check#2	**Written test**

Name: ___________________________ Date: ________________

Directions: Answer questions listed below. Illustrations may be necessary to aid some explanations/answers.

1. Write the start up sequence to operate the fertigation equipments?(5 point)
2. Write the advantage of monitoring fertigation process? (5 point)
3. Explain the problems caused by faulty operation of fertigation equipments? (5 point)

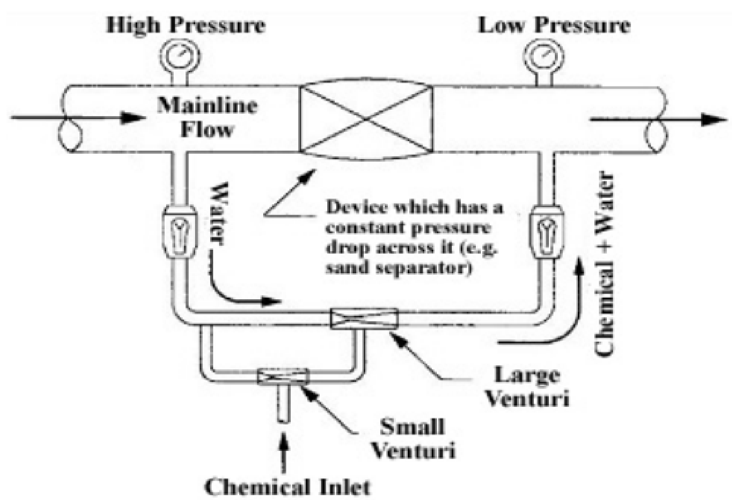
***Note:* Satisfactory rating – 15 points** **Unsatisfactory – below 15 points**

INFORMATION SHEET#3	Shut down fertigation equipment

3.1: Flushing out injection equipment

System flushing

Flushing the injection system reduces to a minimum the accumulation of pollutants, pushing them out of the system. Flushing the irrigation system entails opening the flushing valves in the tanker, injection lines, the sub-main lines or laterals while under pressure. This procedure increases the water flow velocity in the pipes and laterals to clean the internal walls filters of pollutants, flushing them out of the system.



The system must be flushed at regular intervals. The frequency depends mainly on the water quality and the maintenance-flushing program.

Flushing is more effective when the flow rate within the injector, chemical inlet, venturi system, main, and sub-main or dripper lines is increased, flushing contaminants from the internal walls. In some cases, the downstream pressure must be increased in order to enable these flow rates in the main, sub-main or dripper lines.

NOTE: Flushing may be manual or automatic, by opening and washing fertilizer tanker, injection system, the end of the main, sub-main or the dripper line.

Flushing is recommended at least once a month.

Netafim™ offers collector valves and tubes to facilitate flushing.

Flushing Velocities

Location	Recommended rate (m/sec.)
Fertilizer tank	Manual
Injection system	Up on the capable velocity
venturi system	1.5
Main line	1.5
Sub-main line	1.5
Dripperline	0.5

3.2 Cleaning equipment according to enterprise procedures

Cleaning of The Equipments are ;equipping of somebody or something with what is necessary for a particular activity or purpose .

Cleaning is the activity of making things clean, usually in a domestic or commercial environment

3.3 Managing waste generated by both the fertigation process and cleaning procedures

Waste material may include the fertigation by product or the residual parts of fertilizer, un used construction and excavated materials, plant chemical litter and cleaning water the fertigation system and leaks from broken components. Waste may be removed to designated areas for recycling, reuse, and return to the manufacturer or disposal.

Materials may be recycled, re-used, returned to the manufacturer, or disposed of according to enterprise work procedures.

3.4 Repairing and recording fertigation activities

The injection of different treatments may prevent, eliminate, dissolve or solve occurrences of clogging.

The following steps is a guide for determining the order in which to perform chemical injection:

1. Begin by recording the system's flow rate at operating level.
2. Calculate the dose to be injected, based on the recommendations included in this guide.

3. Perform a test injection, in order to verify and/or rectify the correct functioning and the respective flow rate of the injection system.
4. Flush the system according to the instructions in the section "Flushing the System" in this guide.
5. Inject the chemical according to the calculations (point 2) above, depending on the specific treatment.
6. Flush the system, taking into account the advancement times.
7. Removal of chemical residues from the system

Upon completing the injection of products (fertilizers, disinfectants, oxidants, herbicides, etc.), it is recommended to continue irrigating only with water for as long as necessary to remove all residue of these products from the system.

Operation Sheet	Calibration of a fertigation system and clean up system components

Objective: how to calibrate fertigation equipments so that required amount of nutrients can be applied to the crops and clean the system components.

Materials, Tools and equipments used

- ✓ Water
- ✓ Fertilizers(urea, DAP)
- ✓ chlorine,
- ✓ Acid and cleaning agents
- ✓ System component of drip kites
- ✓ Fertilizer tank
- ✓ Watering cane
- ✓ Agitator

Procedures

The following procedures should be taken into account to Calibration of a fertigation system and how to clean up the system compotes:

1. Determine the area to be treated or the number of plants to be treated with a trickle irrigation system.
2. Determine the amount of chemical to be applied per hectare or per plant.
3. Calculate the total amount of chemical to be applied.

4. Determine the length of injection time in hours.
5. Select the chemical composition to be used and mixture concentration.
6. Set the injection flow rate on the injector.
7. Follow start up sequences of operation.
8. Monitor the process.
9. Finally shut down the system components and clean up materials used.