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Ministry of Labor and Skills

Crop Production

Level-III

Based on April 2022, Version1 Occupational Standard

Module Title: - Applying Plant Nutrition Program and Fertigation

LG Code: AGR CRP3 05(1-6) LG (21-26)

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Contents

Introduction to the Module

This module covers the skills, knowledge and attitude required to prepare for implementation of plant nutrition program, Monitor soil pH, Determine nutritional problems in plants, Prepare materials and equipment to apply fertilizers, operate the fertigation process and complete fertigation.

LG #1	LO #1 Prepare for implementation of plant nutrition program

Instruction Sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Introduction to the module • Identifying the goals and targets site of soil fertility • Identifying the availability & storage site for soil and plant treatments materials • Locating services for plant nutrition programme using site plans • Identifying OHS hazards and control their risks • Obtaining Material safety data sheets (MSDS) • Selecting, using & maintaining suitable PPE This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Identify the goals and targets site of soil fertility status • Identify the availability & storage site for soil and plant treatments materials • Locate services for plant nutrition programme using site plans • Identify OHS hazards and control their risks • Obtain Material safety data sheets (MSDS) • Select, use & maintain suitable PPE
Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information sheet 1

1.1 Identification of goals and targets site of soil fertility status

1.1.1 What is plant nutrition program?

Plant nutrition is the study of the chemical elements and compounds necessary for plant growth, plant metabolism and their external supply. Plants, like all other living things, need food for their growth and development. Plants require 18 essential elements. Carbon, hydrogen, and oxygen are derived from the atmosphere and soil water. The remaining nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. For plants to utilize these nutrients efficiently, light, heat, and water must be adequately supplied. Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients is important.

Plant nutrition programs are designed to provide plants with the necessary nutrients for optimal growth and development. These programs can be customized based on the specific needs of the plant and can include fertilization, pest management, and other practices.

Goals and target site for assessment and development of nutrition program are defined following a review of farm's production plan and in consultation with farmers. This is the first step to take soil health development and plant nutrition program because after you defined the goals and target site for the assessment and development you can undertake the next process.

For example your goals may be to achieve appropriate soil conditions and hence depending on this you have to assess the area where to be developed based on the problems of soil health around the area.

1.1.2 Establishing detail plan, objective, specification and associated cost

Detailed plan, objectives, specifications and associated costs are established based on program requirements and are presented to farm manager**.** To document the soil health and plant nutrition program and specifications it is important to establish the detail plan on soil health and plant nutrition program and this plan must have objective which indicates or answers the question why the plan is under taken and this objectives also have specifications which is describes the aim of your objectives and associated cost to undertake soil health development and plant nutrition program in terms of man power, equipment required, machinery required etc.

1.1.3 Importance of implementing of plant nutrition program

- Promote a better understanding of the role of plant nutrients in securing the sustainability of agriculture and in building up and maintaining soil productivity;
- Ensure that all sources of plant nutrients, especially fertilizers, are used efficiently for increased agricultural production;
- Identify how the application of plant nutrients can affect the environment and point to ways of avoiding negative impacts;
- Formulate recommendations for plant nutrition management in a framework of Integrated Plant Nutrition Systems (IPNS), taking into account farmers' production goals and strategies within specific agro ecological, social and economic conditions;
- Promote the development of sound advisory services and efficient input supply systems to farmers;
- Facilitate the emergence of farmers' associations leading to the adoption of sound plant nutrition practices; and
- Provide elements for the design of national strategies and policies for effective plant nutrition in support of agricultural intensification and rural development.

1.1.4 Identifying soil fertility status

Soil condition including texture, fertility, depth, alkalinity, salinity, soil reaction, chemical content, drainage, and water logging which influence the growth and development of agricultural crops must also be considered while selecting a suitable site for agricultural crops. The nutritional requirements of the crop are dependent on factors such as soil fertility, weather, planting age and crop load, all of which change over time.

Therefore, the amount of nutrients the grower needs to provide the crop may also change over time. As the soil is the 'storehouse' for nutrients, the best approach to meeting the nutritional requirements is to establish your crop in fertile, well drained soils with the appropriate soil pH. Once the crop is planted, routine evaluation of plant nutrient status and soil composition are essential to developing sustainable nutrient management practices.

- **Soil Acidity**

Acidity in soils comes from H^+ and Al^{3+} ions in the soil solution and adsorbed to soil surfaces. While pH is the measure of H^+ in solution, Al^{3+} is important in acid soils because between pH 4 and 6, Al^{3+} reacts with water (H_2O) forming $AlOH^{2+}$, and $Al(OH)_2{}^+$, releasing extra H^+ ions. Every Al^{3+} ion can create 3 H^+ ions. Many other processes contribute to the formation of acid soils including rainfall, fertilizer use, plant root activity and the weathering of primary and secondary soil minerals. Acid soils can also be caused by pollutants such as acid rain and mine spoiling.

- **Soil Salinity**

Salt-affected soils consist of saline and sodic soils, occur in all continents and under almost all climatic conditions, but their distribution is relatively more extensive in the arid and semi-arid regions compared to the humid regions. Soil salinization and sodification are major soil degradation processes threatening ecosystem and are recognized as being among the most important problems at a global level for agricultural production, food security and sustainability in arid and semi-arid regions. There are extensive areas of salt-affected soils on all the continents but their extent and distribution have not been studied in detail.

Salt-affected soils have serious impacts on soil functions leading to an array of consequences, including significant decreases in agricultural productivity, water quality, soil biodiversity, and soil erosion. Salt-affected soils have a decreased ability to act as a buffer and filter against pollutants. The degradation of soil structure and functions of global ecological systems such as the hydrological, nutrient and biogeochemical cycles, impair the provision of ecosystem services, which are critical for supporting human life and biodiversity. Salt-affected soils reduce both the ability of crops to take up water and the availability of micronutrients. They also concentrate ions that are toxic to plants and may degrade the soil structure.

Saline soil contains high contents of soluble salts. Sodium salts are predominant in the saline soil. In addition, K^+, Ca^{2+}, Mg^{2+} and Cl^- are also responsible for the salinity of the soil. Hence, it has a basic pH range; 7 – 8.5. In saline soil, exchangeable sodium percentage is less than 15%. But, its electrical conductivity is 4 or more mmhos/cm. The salinity of the soil increases due to various reasons such as mineral weathering, excessive irrigation and the use of fertilizers and animal wastes, etc.

Thus, it negatively affects crop yield. Furthermore, salinity also causes necrosis of leaf margins, stunted plants, wilting and plant death under severe conditions. Reclaiming the soil by leaching with good quality water is a method to reduce the soil salinity. However, this can pollute the groundwater and surface water. Another solution in agriculture for saline soil is the growing of salt tolerant crops.

- **Alkaline soils**

Alkaline soils are clay soils that have a pH greater than 8.5. The high pH is due to the high levels of sodium, calcium, and magnesium. Moreover, hard water can also raise the pH of the soil to alkaline levels. However, the dominating compound in alkaline soil is sodium carbonate. Sodium carbonate causes alkaline soils to swell.

Besides, alkaline soils have an exchangeable sodium percentage greater than 15% and electrical conductivity less than 4 mmhos/cm. Also, similar to saline soils, the availability of plant nutrients in alkaline soil is low. Nevertheless, some plants such as lilies, geraniums and maidenhair fern thrive in this soil. Some examples of high alkaline soils are dense forests, peat bogs and soil with a high quantity of certain minerals.

The key difference between saline and alkaline soils is that pH of the saline soils ranges in between 7 to 8.5 while the pH of the alkaline soils is greater than 8.5. Furthermore, saline soils have an exchangeable sodium percentage of less than 15% while alkaline soils have an exchangeable sodium percentage greater than 15%. So, this is also a difference between saline and alkaline soils.

Moreover, the electrical conductivity of saline soil is high while it is low in alkaline soils. Also, the organic matter content in saline soils is comparatively higher than alkaline soils.

- **Soil organic matter**

Organic matter plays several key roles in soil properties and soil processes. The presence of organic matter improves soil stability by promoting aggregation which reduces the potential for soil erosion. Soil organic matter also improves water retention in soil and has a high cation exchange capacity (from 100 to 500 cmol kg-1) which contributes to the total cation exchange capacity of the soil, depending on the amount of soil organic matter present. This improves the soil's ability to retain important cations (Ca2+, Mg2+, K+, and Na+), that can enhance the buffering capacity of the soil. Soil organic matter is also the most biogeo chemically active and dynamic portion of the soil and it is important for regulating many processes related to the global cycling of elements such as carbon. Soil organic matter acts as a storehouse and a slow release fertilizer for many plant nutrients, including nitrogen, phosphorus and sulfur. Finally, organic matter supports a large and varied faunal and microbial community.

Organic matter improves soil aeration, water infiltration, and both water- and nutrient-holding capacity. Inorganic amendments include vermiculite, perlite, lime, tire chunks, pea gravel and sand. These inorganic amendments help offset any soil nutritional deficiencies, improves aeration, and controls acidity or PH.

1.1.5 Identifying plant species and varieties

Plants are often thought of as passive in relation to the environment. However this is not always a valid assumption; for there are many plants that clearly manipulate their environment in a fashion that tends to makes certain nutrients more readily available. For example, iron is a limiting nutrient in many agricultural areas, but it comprises about 3% of the average soil which, if available, would be far in excess of the needs of the average plant. Some plants actively excrete protons, and the resulting decrease in pH increases the solubility of iron in their environment. In addition, other plants excrete phytosiderophores that chelate the soil iron rendering it a more available form for the plants

Plant species behave in a somewhat characteristic way and this is clearly illustrated by the varying mineral composition of different plant growing together in the same soil or substrate. The following observations have been generally confirmed:

PH 4.5-5.0:- Blueberry, Bilberry, Heather, Cranberry, Orchid, Azalea, for blue Hydrangea (less acidic for pink) , Sweet Gum, Pin Oak.

PH 5.0 - 5.5:- Parsley, Potato, Heather, Conifers, Pine, Sweet Potato, Maize, Millet, Oars, Tye, Radish, Ferns, Iris, Orchids, Rhododendron, Camellia, Daphne and Boronia.

PH 5.5 - 6.0:- Bean, Brussels Sprouts, Carrot, Choko, Endive, Kohl Rabi, Peanuts, Rhubarb, Soybean, Crimson Clover, Aster, Begonia, Canna, Daffodil, Jonquil, Larkspur, Petunia, Primrose, Violet and most bulbs.

PH 6.0 - 6.5:- Broccoli, Cabbage, Cannabis, Cauliflower, Cucumber, Egg Plant, Pea, Sweet Corn, Pumpkin, Squash, Tomato, Turnip, Red Clover, Sweet Clover, White Clover, Candytuft, Gladiolus, Iceland Poppy, Pansy, Rose, Snapdragon, Viola, Wallflower, Zinnea and Strawberry.

PH 6.5 - 7.0:- Asparagus, Beet, Celery, Lettuce, Melons, Onion, Parsnip, Spinach, Lucerne, Carnation, Chrysanthemum, Dahlia, Stock, Sweet Pea and Tulip.
PH 7.1 - 8.0:- Lilac, brassica
There are also other several crops that thrive in acidic soil. Some examples of vegetables that prefer acidic soil include **radishes**, **sweet potatoes**, **parsley**, **peppers**, and **potatoes**. These crops prefer a soil pH of 5.5 to 6.5, though some can tolerate a slightly lower pH and still produce good yields

Crops that are typically grown in alkaline soils include **alfalfa**, **barley**, **corn**, **oats**, **sorghum**, and **wheat**. These crops are well-adapted to alkaline conditions and can often provide higher yields than crops grown in other types of soils.

1.2 Soil and plant treatment materials

Cost-effective approach to soil amendment materials for soil and plant treatments include:

- Use of manure
- Use of farm yard manure

- Proper incorporation of crop residues in to the soil
- Use of cover crop
- Inter cropping
- Crop rotation
- Fallowing and etc.

Others amendment materials include Fertilizers, pre plant amendment materials – gypsum, dolomitic limestone, and microelements and post plant amendment materials – nitrogen, phosphorus, and potassium in a slow-release fertilizer form

1.3 Locating services using site plans

Services or facilities that may include: water supply, gas, power (electricity), telecommunications, irrigation, storm water and drainage that we can use in the implementation plant nutrition program.

1.4 OHS hazards and control their risks

1.4.1 Identifying OHS hazards

Identifying hazards involves finding all of the foreseeable hazards in the workplace and understanding the possible harm that the hazards may cause. *OHS hazards* may include: disturbance or interruption of services, solar radiation, dust, noise, soil-, air- and water-borne micro-organisms, chemicals and hazardous substances, sharp hand tools and equipment, manual handling, moving vehicles, machinery and machinery parts, flying objects and uneven surfaces.

1.4.2 Assessing risk in OHS

Risk assessment is a process for developing knowledge and understanding about hazards and risks so that sound decisions can be taken about control. A risk assessment will provide knowledge to make informed decisions about controlling hazards and risks. The risk assessment needs to be tailored to the situation and to the organization in which it is conducted; it can be as simple as structured discussion during consultation or it can be more elaborate and formal.

Risk assessment assists in determining:

- What levels of harm can occur
- How harm can occur

- The likelihood that harm will occur.

A risk assessment should be done when:

- There is only limited knowledge about a hazard or risk, or about how the risk may result in injury or illness
- There is uncertainty about whether all of the things that can go wrong have been found
- The situation involves a number of different hazards that are part of the same work process or piece of plant and there is a lack of understanding about how the hazards may impact upon each other to produce new or greater risks.

Five Steps to Risk Assessment.

- Identify the hazards.
- Decide who might be harmed and how.
- Evaluate the risks and decide on precautions.
- Record your findings and implement them.
- Review your risk assessment

1.4.3 Controlling hazards and risks

There are many hazards that have the potential to kill, injure or cause ill health or disease. Protecting the health and safety of people is a community expectation that makes good business sense. Workplace incidents can have a dramatic impact on people's lives (people in the workplace, families and friends), and they can have significant financial impacts on organizations through loss of skilled staff and lost production of goods or services.

Arriving at appropriate controls involves:

- Identifying the options for controls.
- Considering the control options and selecting a suitable option that most effectively eliminates or reduces risk in the circumstances.
- Implementing the selected option.

1.5 Material safety data sheets (MSDS)

Material Safety Data Sheet (MSDS) is a fact sheet developed by manufacturers describing the chemical properties of a product. Material Safety Data Sheets include brand-specific information such as physical data (solid, liquid, color, melting point, flash point, etc.), health effects, first aid, reactivity, storage, handling, disposal, personal protection and spill/leak procedures. The target audience for information in a MSDS is the occupation worker who may be exposed to chemicals at work. However, much of the information is also relevant to consumers.

In the context of plant nutrition programs, MSDSs are important documents that provide information on the safe handling, storage and disposal of fertilizers and other plant nutrients. MSDSs can be obtained from the manufacturer or supplier of the product.

1.6 Selecting, using and maintaining suitable PPEs

PPE may include: hat, boots, overalls, gloves, goggles, respirator or face mask, face guard, spray clothing, hearing protection, sunscreen lotion and hard hat.

Occupational health safety aims at:

- ✓ maintenance of the highest degree of physical, mental and social well-being of workers
- ✓ the prevention among workers of adverse effects on health caused by their working conditions;
- ✓ the protection of workers in their employment from risks resulting from factors adverse to health;
  - physical hazards, such as, unsatisfactory lighting, radiation and extreme temperatures;
  - biological hazards, such as bacteria, viruses, infectious waste and infestations;
  - psychological hazards resulting from stress and strain
  - chemical hazards, arising from liquids, solids, dusts, fumes, vapours and gases

1.6.1 Applying Personal Protective Equipment (PPE)

Personal protective equipment, or PPE, is designed to protect workers from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.

Figure 1.1 PPE Equipment

Types of PPE

- Gloves – to protect hands
- Gowns/aprons –to protect skin and/or clothing
- Masks and respirators– to protect mouth/nose
- Respirators – to protect respiratory tract
- Goggles – to protect eyes
- Face shields – protect face, nose, mouth, and eyes

Factors influencing PPE selection consider three key things;

1. Type of exposure expected
    - Splash/spray versus touch
2. Durability and appropriateness for the PPE for the task
3. PPE must fit the individual user

How to safely use PPE

- Use protective equipment properly,
- Be aware of when personal protective equipment is necessary,
- Know what kind of protective equipment is necessary,
- Understand the limitations of personal protective equipment in protecting workers from injury,
- Put on, adjust, wear, and take off personal protective equipment, and
- Maintain protective equipment properly.

Self-Check 1	Written Test

Name: __________________________ ID________ Date: ________________

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

Test I: Matching

A	B
1. PPE	A. Soil fertility
2. Hazards	B. Physical data
3. Risk assessment	C. Causes harm
4. Material safety data sheet	D. Prevent injuries
5. Soil condition	E. Identify hazards

Test II: Short Answer Questions

1. Define plant nutrition.
2. Discuss the important of implementing plant nutrition.
3. Write the difference between soil acidity, alkalinity and soil sodicity.
4. Explain how to assess OHS risk during implementing plant nutrition.
5. Write the PPE equipment we use in farm activities.

LG #2	LO #2 Monitoring soil pH

Instruction Sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Monitoring the soil pH • Identifying, comparing, selecting and sourcing materials to change soil pH • Assessing impacts of product application methods to change soil pH on environment This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Monitor the soil pH • Identify, compare, select and source soil pH changing materials • Assess impacts of product application methods to change soil pH on environment
Learning Instructions:
1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3. Read the information written in the information Sheets 4. Accomplish the Self-checks 5. Perform Operation Sheets 6. Do the "LAP test"

Information Sheet 2

2.1 Monitoring soil pH in the implementation site

Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. Soil pH is defined as the negative logarithm of the hydrogen ion concentration. The pH scale goes from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases the soil pH decreases thus becoming more acidic. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic.

Descriptive terms commonly associated with certain ranges in soil pH are:

- Extremely acid, < than 4.5
- Very strongly acid, 4.5 - 5.0
- Strongly acid 5.1 - 5.5
- Moderately acid, 5.6 - 6.0
- Slightly acid, 6.1 - 6.5,
- Neutral, 6.6 - 7.3,
- Slightly alkaline, 7.4 - 7.8
- Moderately alkaline, 7.9 - 8.4
- Strongly alkaline, 8.5 - 9.0
- Very strongly alkaline, > than 9.1; lime = 12

2.1.1 Measuring Soil pH

Methods of determining pH include:

I. **Observation of soil profile**

Certain profile characteristics can be indicators of either acid, saline, or sodic conditions. Strongly acidic soils often have poor incorporation of the organic surface layer with the underlying mineral layer. The mineral horizons are distinctively layered in many cases, with a pale eluvial (E) horizon beneath the organic surface; this E is underlain by a darker B horizon in a classic podzol horizon sequence. This is a very rough gauge of acidity as there is no correlation between thickness of the E and soil pH.

II. Observation of predominant flora.

Calcifuges plants (those that prefer an acidic soil) include *Erica*, *Rhododendron* and nearly all other Ericaceae species, many birch (*Betula*), foxglove (*Digitalis*) , gorse (*Ulex* spp.), and Scots Pine (*Pinus sylvestris*). Calcicole (lime loving) plants include ash trees (*Fraxinus* spp.), honeysuckle (*Lonicera*), *Buddleja*, dogwoods (*Cornus* spp.), lilac (*Syringa*) and *Clematis* species.

III. **Use of an inexpensive pH testing kit**

Based on barium sulphate in powdered form, where in a small sample of soil is mixed with water which changes color according to the acidity/alkalinity.

IV. Use of litmus paper

A small sample of soil is mixed with distilled water, into which a strip of litmus paper is inserted. If the soil is acidic the paper turns red, if alkaline, blue.

V. Use of a commercially available electronic pH meter

In which a rod is inserted into moistened soil and measures the concentration of hydrogen ions.

2.2 Soil acidity, alkalinity and salinity

2.2.1 Soil acidity

Soils tend to become acidic as a result of:

- Rainwater leaching away basic ions (calcium, magnesium, potassium and sodium);
- Carbon dioxide from decomposing organic matter and root respiration dissolving in soil water to form a weak organic acid;
- Formation of strong organic and inorganic acids, such as nitric and sulfuric acid, from decaying organic matter and oxidation of ammonium and sulfur fertilizers. Strongly acid soils are usually the result of the action of these strong organic and inorganic acids.

Lime is usually added to acid soils to increase soil pH. The addition of lime not only replaces hydrogen ions and raises soil pH, thereby eliminating most major problems associated with acid soils but it also provides two nutrients, calcium and magnesium to the soil. Lime also makes phosphorus that is added to the soil more available for plant growth and increases the availability of nitrogen by hastening the decomposition of organic matter. Liming materials are relatively inexpensive, comparatively mild to handle and leave no objectionable residues in the soil.

Some common liming materials are:

- Calcic limestone which is ground limestone;
- Dolomitic limestone from ground limestone high in magnesium; and
- Miscellaneous sources such as wood ashes.

The amount of lime to apply to correct a soil acidity problem is affected by a number of factors, including soil pH, texture (amount of sand, silt and clay), structure, and amount of organic matter. In addition to soil variables the crops or plants to be grown influence the amount of lime needed. In addition to monitoring soil pH the nutrient status of the soil should be examined.

2.2.2 Soil alkalinity

Soil alkalinity refers to soil with a pH greater than 7. It is also known as "sweet soil" and tends to contain high levels of sodium, calcium, and magnesium. It is less soluble than acidic or neutral soil, which may limit the availability of nutrients. It is very common in semiarid and arid climates and has a poor soil structure and low infiltration capacity

2.2.3 Soil salinity

Salts from inorganic fertilizer, fish bone meal, compost and manure applications can accumulate to the point where they harm plant growth. Soil salinity is most commonly a problem in greenhouse soils. In outdoor gardens, salts are usually leached from the soil with normal watering and rainfall, so salt does not accumulate in the root zone unless fertilization is excessive.

A salinity test measures the total soluble salts in a soil. It measures soluble salts indirectly by measuring the electrical conductivity (EC) of a soil/water solution. The excess water must drain downward through the soil to carry away excess salts. When leaching, apply water slowly enough that it infiltrates the surface and drains freely through the subsoil.

2.3 Identifying, comparing, selecting and sourcing products useful in changing soil pH

Products useful in changing soil pH may include lime such as ground limestone, dolomite, and a range of fertilizers. Most plants grow best in a slightly acid soil. If the pH rises (becomes more basic) or lowers (becomes more acid), some elements become less available for plant uptake. Low pH soils are neutralized by adding limestone (calcium carbonate) to the soil. Some limestone, such as dolomitic limestone, also contains magnesium (Mg). For all horticultural uses, agricultural ground limestone or ground dolomitic limestone is recommended. High pH soils can be neutralized by adding an acid forming material such as finely ground sulfur (S), peat moss, or by using an acid forming fertilizer to the soil.

Factors to consider when choosing an amendment

There are at least four factors to consider in selecting a soil amendment:

- how long the amendment will last in the soil,
- soil texture,
- soil salinity and plant sensitivities to salts, and
- salt content and pH of the amendment

2.3.1 Increasing soil pH

The most common way to increase soil pH is to add lime. Lime is ground limestone, a rock containing calcium carbonate. It is a natural amendment, suitable for use by organic gardeners. Lime raises the pH of acid soils and supplies Calcium, an essential nutrient.

Dolomitic lime contains Magnesium as well as Calcium, so it is a good choice if soil magnesium is low. Lime is a slow-release material. Apply it in the fall and incorporate it for best results. Wood ashes are a readily available source of Potassium, Calcium and Magnesium. Like lime, they also raise soil pH. Composts are often slightly alkaline and can increase soil pH to a limited extent. Gypsum (Calcium Sulfate) is not a substitute for lime. It supplies calcium and sulfur and is a good fertilizer material for both of those nutrients when they are low, but it has little effect on soil pH. Gypsum has been promoted as a soil amendment to improve soil structure. In the majority of cases, it does not work for this purpose.

For calcium carbonate the reaction is:

$$CaCO_3 + 2H^+ \Leftrightarrow Ca^{2+} + CO_2 + H_2O$$

For dolomitic lime the reaction is:

$$CaMg(CO_3)_2 + 2H^+ \Leftrightarrow 2HCO_3^- + Ca^{2+}\ Mg^{2+}$$

$$2HCO_3^- + 2H^+ \Leftrightarrow 2CO_2 + 2H_2O$$

For Cal-Sil or calcium silicate lime, the reaction is:

$$CaH_2SiO_4 + 2H^+ \Leftrightarrow Ca^{2+} + H_4SiO_4$$

2.3.2 Decreasing soil pH

You may need to decrease soil pH if you wish to grow acid-loving plants. Elemental sulfur lowers soil pH and is the most commonly used material. Iron sulfate also lowers pH and acts more rapidly than sulfur, but it takes more material and is more expensive. Ammonium sulfate and urea fertilizers can help maintain low pH, but they should not be applied at rates higher than required to meet the nitrogen requirement of the crops grown. Some organic materials like sphagnum peat moss also lower pH.

Factors which contribute to a soil becoming acidic include:

Leaching: Refers to the washing down of plant nutrients below the soil beyond the reach of the plant roots leaving behind hydrogen ion.

Use of acid fertilizers: The use of acid fertilizers like ammonium sulphate and ammonium nitrate can easily cause acidity in the soil.

Nutrient uptake by plants: the absorption of soluble minerals by plants results in the accumulation of hydrogen ions which cause soil acidity.

Presence of acid parent materials: The presence of acid parent materials results in the easy dissolution of the rocks, leaving behind minerals rich in hydrogen ions.

Presence of Sulphur in the soil: Sulphur undergoes oxidation and dissolution to form acid in the soil. Soil acidity can be ameliorated through liming and application of organic manure can also be used on the soil to remove acidity

2.4 Product application methods and environmental implications

2.4.1 Types of product application methods;

- Band placement or raw placement
- Hill placement
- Ploughing in green

- Side dressing
- Foliar application
- Fertigation

Agricultural limestone may be applied any time prior to crop establishment. Lime is often distributed over the fields by means of spreading attachments on large trucks in which the material is hauled in bulk from the railroad car or stock pile directly to the field. The method practically eliminates hand labor, relieves the farmer of an unpleasant job, and expedites the handling of the material. The trucks are most commonly equipped with two rotating horizontal plates at the rear for spreading the material and a conveyor in the bottom of the truck bed ; the conveyor feeds the material to the scattering plates at the desired rates. Other equipment includes various types of hoppers with spreaders mounted on the truck or trailed behind it. In the latter case, hand labor is usually required for transferring the material from the truck bed to the hopper of the spreading equipment. The most recent developments include improvements in the conveying mechanism and spreader plates for more positive operation and more uniform spreading of the material.

Figure 2.1 Application of lime

Broadcasting: A recommended rate of lime is spread over the growing area and left to filter into the soil, or is incorporated into the soil with a cultivator. Broadcasting is the application method generally used for large field areas, when time or labor are limited, or when it is important to obtain a uniform distribution of the soil amendment, as with a liming material.

2.4.2 Identifying environmental implications of program

Lime is the oldest traditional stabilizer used for soil stabilization. The mechanism of soil-lime treatment involves cation exchange, which leads to the flocculation and agglomeration of soil particles. The high pH environment then causes a pozzolanic reaction between the free Ca+2 cations and the dissolved silica and alumina. Lime-treated soil effectively increases the strength, durability and workability of the soil. Such treatment also improves soil compressibility. A fluctuation behavior was observed on the influence of lime on soil permeability. However, the factors affecting the permeability of the soil-lime mixture should be extensively studied. Nonetheless, lime treatment has a number of inherent disadvantages, such as carbonation, sulfate attack and environment impact. Magnesium oxide/hydroxide are thus proposed as a suitable alternative stabilizer to overcome at least some of the disadvantages of using lime in soil stabilization.

The application of more irrigation water without proper drainage leads to an increase in soil salinity and alkalinity. This can damage vegetation and disturb the ecosystem balance. The text also highlights the important problems related to fertilizer vis-a-vis environmental quality such as nitrate pollution of groundwater, eutrophication of lake and river water, increased emission of gaseous nitrogen, and metal toxicities. The injudicious use of chemicals deteriorates land quality and contaminates water, food and environment. The spurt in the pesticide use has resulted in secondary pest outbreak. The pesticide residues in soil may create a variety of hazards. Soil micro-organisms which cause breakdown of cellulose, nitrification, turn over of organic matter, and other biological materials may be adversely affected by pesticides. Pesticides and chemicals inhibit the microbial population in soil, thereby resulting in reduced nitrogen fixation by symbiotic bacteria. There may be a serious decline in population of earthworm due to pesticide residues and this affects crop yields.

Self-check 2	Written test

Name:________________________________ID______________date__________________

Direction: answer the following question. Pay attention in each activity and try to answer to the point.

Test I: Matching

A	**B**
1. Soil pH	A. Acidity/alkalinity measure
2. Strongly alkaline	B. pH(5.1 - 5.5)
3. Strongly acid	C. pH(8.5 - 9.0)
4. Limestone	D. Workplace
5. Leaching	E. Acidifying factor
	F. Organic matter

Test II: Short Answer Questions

1. Discuss the factors which contribute to a soil becoming acidic.
2. What are the common liming materials?
3. Define soil pH and how soil pH monitored
4. What are the factors that increase soil acidity?
5. How pH determine the availability of plant nutrient?

Operation Sheet 2.1

2.1 Soil reaction (pH)

A. Objectives

- To identify alkalinity or acidity of soil

B. Apparatus required

- pH meter with glass electrodes
- Thermometer
- Glass beaker (100 ml)
- Glass rod

C. Procedure

1. Weigh 20 gm of 2.0 mm air dry soil into a beaker. Add 50 ml of distilled water and stir with a glass rod thoroughly for about 5 minutes and keep for half an hour.
2. In the mean time turn the pH meter ON, allow it to warm up for 15 minutes. Standardize the glass electrode using standard buffer of pH = 7 and calibrate with the buffer pH = 4 or pH = 9.2.
3. Dip the electrodes in the beakers containing the soil water suspension with constant stirring.
4. While recording pH, switch the pH meter to pH reading, wait 30 seconds and record the pH value to the nearest 0.1 unit. Put the pH meter in standby mode immediately after recording
5. Remove the electrodes from soil suspension and clean the electrodes with distilled water.
6. Rinse the electrodes after each determination and carefully blot them dry with filter paper before the next determination. Standardize the glass electrodes after every 10 determinations.

7. Dip the electrodes in distilled water, when not in use and ensure that the reference electrode always contains saturated potassium chloride solution in contact with solid potassium chloride crystals.
8. Three to four drops of toluene are added in standard buffer solutions to prevent growth of mold.

Rate the pH meter reading with the following values and associated terms

- <4.5 Extremely Acidic
- 4.6 to 5.2 Strongly Acidic
- 5.3 to 6.0 Moderately Acidic
- 6.1 to 6.5 Slightly Acidic
- 6.6 to 7.0 Neutral
- 7.1 to 7.5 Slightly Alkaline
- 7.6 to 8.3 Moderately Alkaline
- 8.4 to 9 Strongly Alkaline
- > 9 Extremely Alkaline.

Operation Sheet 2.2

2.1 Plant tissue analysis

A. Objectives

- To familiarize the trainee with Plant tissue analysis

B. Material required

- Potassium test paper (3 spots on the paper(3 spots on paper)
- Nitrate powder
- Sample bag
- P-K reagent No1 and P-reagent No2
- Sharp knife
- Needle nosed pliers

C. Procedures

1. Take a plant sample (petiole or stem) from field
2. Cut the portion of the green plant tissue and place on folds test paper
3. Add nitrate powder to the tissue and squeeze together.
4. Then observe the color changes and report to your instructor

LG #3	LO #3 Determining nutritional problems in plants

Instruction Sheet

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

- Identifying plant nutrient deficiency and toxicity problems
- Enlisting causes of nutritional problems and toxicity
- Explaining mechanisms of nutrient cycling and nutrient uptake
- Identifying oil amelioration methods

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify effects of plant nutrient deficiency and toxicity problems
- List causes of nutritional problems and toxicity
- Explain mechanisms nutrient cycling and nutrient uptake
- Identify soil amelioration methods

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the "LAP test"

Information sheet 3

3.1 Plant nutrient deficiency and toxicity problems

3.1.2 Identifying common nutrient deficiency and toxicity problems in plants using visual inspection

Interpreting visual nutrient deficiency and toxicity symptoms in plants can be difficult and plant analysis or soil testing is necessary to confirm nutrient stress.

It is unusual to find any one leaf or even one plant that displays the full array of symptoms that are characteristic of a given deficiency. It is thus highly desirable to know how individual symptoms look, for it is possible for them to occur in many possible combinations on a single plant.

Acute deficiency occurs when a nutrient is suddenly no longer available to a rapidly growing plant. Chronic deficiency occurs when there is a limited but continuous supply of a nutrient, at a rate that is insufficient to meet the growth demands of the plant.

Most of the classic deficiency symptoms described in textbooks are characteristic of acute deficiencies. The most common symptoms of low-grade, chronic deficiencies are a tendency towards darker green leaves and stunted or slow growth. Typically most published descriptions of deficiency symptoms arise from experiments conducted in greenhouses or growth chambers.

Stresses such as salinity, pathogens, and air pollution induce their own characteristic set of visual symptoms. Often, these symptoms closely resemble those of nutrient deficiency

The three basic tools for diagnosing nutrient deficiencies and toxicities are

- Soil testing;
- Plant analysis; and
- Visual observations in the field.

Visual nutrient deficiency symptoms can be a very powerful diagnostic tool for evaluating the nutrient status of plants. One should keep in mind, however, that a given individual visual symptom is seldom sufficient to make a definitive diagnosis of a plant's nutrient status.

Their main drawback is that the visual symptoms do not develop until after there has been a major effect on yield, growth and development.

Although visual diagnostic symptoms are an extremely valuable tool for the rapid evaluation of the nutrient status of a plant, they are only some of the tools available. Other major tools include microscopic studies, spectral analysis, and tissue and soil analysis. These methods all vary in their precision, rapidity and their ability to predict future nutrient status. Because of the close interaction between plant growth and the environment, all predictions of future nutrient status must make assumptions about how the environment will change in that time frame.

Table 3.1 Symptoms of nutrient deficiency and toxicity problems

Nutrient	**Deficiency Symptoms**	**Comments**	**Toxic Symptoms**
MACRONUTRIENTS-Replace macronutrients in soils regularly (at least once per growing season)			
Calcium (Ca)	New leaves (top of plant) are distorted or irregularly shaped. Causes blossom-end rot.	Desert soils and water generally have plenty of calcium, so deficiency problems are rare. Excessive calcium can limit the availability of other nutrients.	Excess calcium in soil can kill plants by causing a toxic buildup of nutrients in the plant tissue. This can lead to a number of problems, including nutrient imbalances, stunted growth, and death
Nitrogen (N)	General yellowing of older leaves (bottom of plant). The rest of the plant is often light green.	Most plants absorb nitrogen in the form of ammonium or nitrate.These forms readily dissolve in water and leach away.	Vigorous vegetative growth , dark green colour , prolonged growing (vegetative) period and delayed crop maturitiy." Also manures.

Magnesium (Mg)	Older leaves turn yellow at edge leaving a green arrowhead shape in the center of the leaf.	Plants absorb magnesium as an ion (charged particle), which can be readily leached from soil. May be readily leached from soil if calcium is not present.	Too much magnesium inhibits the uptake of calcium, and the plant displays general symptoms of an excess of salts; stunted growth, and dark-colored vegetation.
Phosphorus (P)	Leaf tips look burnt, followed by older leaves turning a dark green or reddish-purple.	Plants absorb phosphorus in the form of phosphate. This form dissolves only slightly in water,but pH strongly affects uptake.	P toxicity can result in the death of the plant. Excess of P appears mainly in the form of micronutrient deficiency mostly for Fe, Zn and Mn. Excess P may also cause typical Ca deficiency symptoms.
Potassium (K)	Older leaves may wilt, look scorched. Interveinal chlorosis begins at the base, scorching inward from leaf margins.	Plants absorb potassium as an ion, which can be readily leached from soil. Desert soils and water generally have plenty of potassium, so deficiency problems are rare.	Affects the availability of other nutrients in the soil for the plant.
Sulfur (S)	Younger leaves turn yellow first, sometimes followed by older leaves.	Plants absorb sulfur in the form of sulfate. This readily leaches from the soil. Sulfur may acidify the soil (lower the pH).	Can inhibit the growth of roots, which can reduce the ability of plants to absorb nutrients and water from the soil. Excess sulfur can also interfere with the uptake of certain nutrients, such as iron and zinc, leading to deficiencies in these essential

			elements
MICRONUTRIENTS-Replace when deficiency symptoms are evident			
Boron (B)	Terminal buds die, witches' brooms form.	Plants absorb boron in the form of borate. Problems are seen in intensely cropped areas.	Yellowing of the leaf tip followed by gradual necrosis of the tip and leaf margins, which spreads towards the midrib (central vein).
Copper (Cu)	Leaves are dark green, plant is stunted.	Plants absorb copper as an ion. Arizona soils have plenty of copper, so problems are rare.	More variable with species and less established than its deficiency symptoms. Excess Cu induces Fe deficiency and, therefore, chlorosis is a common symptom.
Iron (Fe)	Yellowing occurs between the veins of young leaves.	Plants absorb iron as an ion through their foliage as well as their roots. Uptake is strongly affected by pH. Chelated iron is readily available for use by the plant, other forms of iron may be tied up in the soil.	Excess iron can produce symptoms of stunted growth and discolored bronzing foliage in plants.
Manganese (Mn)	Yellowing occurs between the veins of young leaves. Pattern is not as distinct as with iron. Palm fronds are stunted and deformed,	Plants absorb manganese as an ion through their foliage as well as their roots.	Lead to the development of brown spots, mainly on older leaves and uneven green colour. Some disorders caused by Mn toxicity are: crinkle leaf spot in cotton; stem streak; necrosis of potato; and internal bark necrosis of apple trees.

	called "frizzle top." Reduction in size of plant parts (leaves, shoots, fruit) generally. Dead spots or patches		
molybdenum (Mo)	General yellowing of older leaves (bottom of plant). The rest of the plant is often light green.	Plants absorb molybdenum in the form of molybdate. But occasionally seen on legumes where it mimics nitrogen deficiency	Extremely rare and characterized by relatively mild symptoms such as yellowish leaves or reduced seedling growth and increased anthocyanin concentrations.
Zinc (Zn)	Terminal leaves may be rosetted, and yellowing occurs between the veins of the new leaves.	Plants absorb zinc as an ion through their foliage as well as their roots. High pH may limit availability	Can result in reduction in root growth and leaf expansion followed by chlorosis.

3.2 Causes of nutritional or toxicity problems

3.2.1 Causes of acidic soils

Plant competition and induced deficiencies

When the observed symptoms are the direct result of a nutrient deficiency, the actions needed for correction are relatively straight-forward. However symptoms are often the result of interactions with other environmental factors limiting the availability of the nutrient whose symptoms are expressed.

The classic instance is that of iron deficiency induced by an excess of heavy metals in the environment. Transition metals such as Cu, Zn Cr and Ni compete with Fe and each other for plant uptake. Competition for uptake is not specific to Fe and heavy metals but is true for all mineral nutrients that are chemically similar and have similar uptake mechanisms.

For example if the availability of Cu or Zn is relatively less than that of Fe, then excessive concentrations of some other metal such as Ni or Cr will induce a deficiency of one of these nutrients rather than Fe. In the case of the macronutrients, excessive amounts of Mg will compete with K for uptake and can possibly induce a K deficiency.

The toxicity of a low pH soil is another example of a basic nutrient deficiency. Low pH has a two-fold effect on soil nutrients: It enhances the leaching of cations, reducing their availability in the soil, and the relatively abundant protons in the soil compete with Ca and other cations for uptake. Thus, Nutrient deficiencies can be induced by a number of different mechanisms often working in concert to limit the availability of a nutrient.

Rainfall: Acid soils are most often found in areas of high rainfall. Excess rainfall leaches base cation from the soil, increasing the percentage of Al^{3+} and H^+ relative to other cations. Additionally, rainwater has a slightly acidic pH of 5.7 due to a reaction with CO_2 in the atmosphere that forms carbonic acid.

Fertilizer use: Fertilizers are categorized into one of two groups: acid-residue or alkaline-residue. The fertilizers themselves are not acidic or alkaline, but they react with microorganisms in the media and plant roots to affect media solution pH. Fertilizers with ample ammonium or urea tend to acidify the media, i.e., lower the pH. Fertilizers with ample nitrates tend to raise the pH of the media solution slowly over time. Ammonium (NH_4^+) fertilizers react in the soil in a process called Nitrification to form nitrate (NO_3^-), and in the process release H^+ ions.

Plant root activity: Plants take up nutrients in the form of ions (NO_3^-, NH_4^+, Ca^{2+}, $H_2PO_4^-$, etc.), and often, they take up more cations than anions. However plants must maintain a neutral charge in their roots. In order to compensate for the extra positive charge, they will release H^+ ions from the root. Some plants will also exude organic acids into the soil to acidify the zone around their roots to help solubilize metal nutrients that are insoluble at neutral pH, such as iron (Fe).

Weathering of minerals: Both primary and secondary minerals that compose soil contain Al. As these minerals weather, some components such as Mg, Ca, and K, are taken up by plants, others such as Si are leached from the soil, but due to chemical properties, Fe and Al remain in the soil profile. Highly weathered soils are often characterized by having high concentrations of Fe and Al oxides.

Acid Rain: When atmospheric water reacts with sulphur and nitrogen compounds that result from industrial processes, the result can be the formation of sulphuric and nitric acid in rainwater. However the amount of acidity that is deposited in rainwater is much less, on average, than that created through agricultural activities.

Water Quality: Water has a capacity to neutralize acids. In other words, irrigating with bicarbonates in water is equivalent to applying lime with each irrigation. The bicarbonates react with hydrogen ions and remove them from solution. This process effectively decreases the H+ ion concentration in the media and thus increases the media solution pH.
The reverse situation can also occur. Very pure water (low bicarbonates) can cause media solution pH to decrease over time. The pH drops, because there may not be enough bicarbonate to absorb excess hydrogen ions. Thus, the H+ concentration in the media increases. The most common solution for pure water sources is to increase the amount of pulverized dolomitic limestone incorporated into the media prior to transplanting plants into the media. Another solution is to top-dress containers with the limestone. Finally, bicarbonate can be added to irrigation water in the form of potassium bicarbonate to improve the buffering capacity of the media solution (i.e., reduce pH fluctuation).

3.2.2 Causes of soil Alkality

Soil sodicity can be attributed either to natural conditions or anthropogenic activities. While natural causes include factors such as climate, lithology, topography, and pedology, human causes are mostly related to agricultural land-use, and specifically, to irrigated agriculture .
The primary source of irrigation-induced soil salinity and sodicity includes the use of fertilizers and minerals (such as gypsum, potash, etc.) and salt-intensive groundwater without adequate treatment.

Basic soils have a high saturation of base cations (K^+, Ca^{2+}, Mg^{2+} and Na+). This is due to an accumulation of soluble salts are classified as either saline soil, sodic soil, saline-sodic soil or alkaline soil. All saline and sodic soils have high salt concentrations, with saline soils being dominated by Ca and Mg salts and sodic soils being dominated by Na. Alkaline soils are characterized by the presence of carbonates.

3.2.3 Causes of saline soil

Soil salinization occurs when soluble salts are retained in the earth. It happens either naturally or because of improper anthropogenic activities, particularly farming practices. Besides, some earths are initially saline due to low salt dissolution and removal. Soil salinization causes include:

- Dry climates and low precipitations when excessive salts are not flushed from the earth;
- High evaporation rate, which adds salts to the ground surface;
- Poor drainage or waterlogging when salts are not washed due to a lack of water transportation;

3.3 Nutrient cycling and nutrient uptake

The improved management of crop nutrients can enhance the bio-availability of macro- and micro-nutrients in crops and grains, a prerequisite for satisfactory crop growth and optimum quantity and quality yields. In addition to water, sunlight and favourable soil conditions, essential nutrients are crucial to optimize crop production and improve the plants' resilience to climate change.

The processes underlying the cycling of nutrients to better understand which soil properties determine the performance of that function. Four processes are identified

I. The capacity to receive nutrients,
II. The capacity to make and keep nutrients available to crops,
III. The capacity to support the uptake of nutrients by crops and
IV. The capacity to support their successful removal in harvested crop.

Soil properties matter but it is imperative that, as constituents of 'soil quality', they should be evaluated in the context of management options and climate and not as ends in their own right. The effect of a soil property may vary depending on the prevailing climatic and hydrologic conditions and on other soil properties. We recognize that individual soil properties may be enhancing one of the processes underlying the cycling of nutrients but simultaneously weakening others. Competing demands on soil properties are even more obvious when considering other soil functions such as primary production, purification and flow regulation of water, climate modification and habitat provision, as shown by examples. Consequently, evaluations of soil properties and management actions need to be site-specific, taking account of local aspects of their suitability and potential challenges

3.4 Soil amelioration

3.4.1 Identifying, Comparing, Selecting and Sourcing soil ameliorants

Soil amendments are any material added to the soil to enhance or increase nutrient content or availability. Lime, fertilizer, manure, compost, etc. This helps to neutralize the acidity of the soil. The free hydrogen ions are taken out of solution. This also helps to increase the pH. This reaction demonstrates the process of liming In some cases, the soil may have very high pH and need to be made more acidic. This can be done by using sulfur, aluminum sulfate, or ammonium sulfate.

Soil amendments are additives to the soil to make the soil fertile so that it provides the necessary nutrients for the crops grown. Amendments are added to improve the physical properties of the soil including water retention, water infiltration, permeability and aeration. The common amendments include fertilizers and soil conditioners. Thus soil amendments enhance the richness of the soil to provide better environment for the roots. Soil ameliorants may include cover crops, animal manures etc.

Certain amendments are just placed on the layer of the soil. Mulching is an amendment that is left on the soil surface. This is done mainly to prevent evaporation and create attractive appearance. Other amendments are mixed with the soil. Burying the amendments is not a good way to improve the soil performance. These amendments must be thoroughly mixed with the soil to do their work properly. Also you must add amendments in appropriate quantities otherwise it will lead to an adverse effect

3.4.2 Types of soil amendments

There are two categories of amendments - organic and inorganic. The organic amendments are made from natural products. The common organic amendments are sphagnum peat, wood chips, straw, saw dust, compost and manure. The wood chips are mainly used as mulches. These increase the organic constituents of the soil thus providing favorable environment for bacteria and earthworms that enrich the soil.

The inorganic amendments are man-made and they include chemicals that are used for making the soil fertile. Though they are used for good output they will reduce the natural nutrients of the soil in the long run.

3.4.3 How to choose soil amendment

The soil amendments depend greatly on the soil requirements. The types of crops that grow in the soil are important before deciding on the amendment. The other factors include the texture of the soil and its salinity. The amount of amendments depends on the duration you want the amendment to stay in the soil. Before using the amendments, they have to be tested for the organic matter and the pH content.

If you want the soil to improve quickly you have to choose the amendments that decompose at a faster rate. Otherwise composts can be used which decompose slowly. Sandy soils are amended to increase the moisture retaining capacity of the soil. Clay soils are amended to increase permeability and aeration. If you choose the appropriate amendments wisely you can benefit from any type of soil.

I. Organic Soil Amendments

Cover crops

Cover crops and green manures are grown primarily for reasons other than short term economic gain. In other words, they are not produced for sale, but rather for the benefits they provide to the production of subsequent cash crops. Cover crops are so-called because they protect otherwise bare soil against erosion; green manures improve soil fertility.

Potential benefits of cover crops are:

- Reducing the impact of wind and water passing over the soil surface can reduce erosion.
- Adding organic matter to soil improves its physical condition, or structure.

- Competing for light, water and nutrients may suppress weeds.
- Legume cover crops add "free" symbiotically-fixed nitrogen to the farming system.
- Crops growing late in the season can capture and "recycle" soluble nutrients otherwise lost.
- Providing cropping system diversity may create habitats for beneficial insects.

Animal manures

Animal manures are an important part of any farming system that does not rely on purchased fertilizers. They are a cheap source of valuable nutrients for crop growth and contribute significantly to the long-term fertility of the soil. However, much of the nutrient value contained in animal manures can be lost by incorrect handling and storage of the material.

Animal manures contain important plant nutrients such as nitrogen, phosphorus, potassium and also trace elements. As manures break down in the soil, crop nutrients are supplied gradually over a period of time. Animal manures therefore provide nutrients for immediate crop growth and also for future yields. When a soil has enough organic matter, it is able to retain moisture which improves the soil's ability to sustain crop growth in times of drought.

A soil with good organic matter also has improved structure which helps drainage and air circulation. By improving soil structure, soil erosion is reduced. The soil is more stable, soil compaction is minimised and nutrients are retained. The use of artificial fertilizer does not benefit the soil in these ways, but by-passes the soil organisms and provides nutrients instead directly to the plant. This results in the decrease of soil structure, soil stability and 'soil life', which is indicated by the presence of micro- and macro-organisms.

Compost

Compost is one the best friends a gardener can have. Just about all vegetation (tress, fruits, vegetables, shrubs, etc) thrive on compost or mulch. Pumpkins are no exception. Most gardeners have a compost pile where we throw anything and everything from the plant world. Most of us are not picky at what we throw in there and most vegetation are perfectly fine to include in our compost pile.

Make sure the things you put in the compost pile are clean and free of bacteria. If you had bacterial wilt or other disease problems with your crop, do not throw it on the compost heap. If the pile is not hot enough, the disease will winter in your compost pile and re-infest the next

Leaves and Leaf Mulch (Black Gold):

Leaves are a frequent additive to the garden. Most (but not all) leaves are fairly neutral in ph, and overall are healthy for the soil and plants.

There are other mulches as well. These include pine mulch and wood chips. The drawback to some of these are acidic pH levels, little nutrient value, or raw compost which can result in burning your plant if piled too thickly. I once used thick layers of pine needles on my garden. It worked great to keep the weeds down

Crop Rotation:

Crop rotation means moving your crop from one area of your garden or field to another. This is and important concept for home gardeners as well as professional farmers in order to maintain the health of your soil. Rotating your crops helps to avoid depletion of nutrients and minerals in the soil. And, very importantly, it minimizes insect and disease as both of these can overwinter in your soil.

II- Organic Soil Amendments

Gypsum

In the estimation of gypsum requirement of saline-sodic/sodic soils, the attempt is to measure the quantity of gypsum (Calcium Sulphate) required to replace the Na from the exchange complex. The Na so replaced with the Ca of the gypsum is removed through leaching of the soil. The soils treated with gypsum become dominated with Ca in the exchange complex. When the Ca of the gypsum is exchanged with Na, there is a reduction in the Ca concentration in the solution. The quantity of Ca reduced is equivalent to the Ca exchanged with Na. It is equivalent to the gypsum requirement of the soil when “Ca” is expressed as $CaSO_4$.

Lime

Crop yields are normally high in soils with pH values between 6.0 and 7.5. Lime is added to raise the pH of acid soils, and the amount of lime required to raise the pH to an optimal level is called lime requirement. Various methods are available for determining the lime requirement.

The methods discussed here are based on the use of a buffer solution, whose pH undergoes change when treated with acid soils. The pH of the buffer solution decreases gradually as H+ ion concentration increases.

Self-Check 3	Written Test

Name: _________________________ ID__________ Date: _______________

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

Test I: Write True or False

1. Cover crops and green manures produced for short gain profits
2. Industrial fertilizers are a typical kind of organic soil amendments
3. Type of soil amendment to use depends on the type of crop to be produced.
4. Soil amendments are material added to the soil mainly to enhance its physical property
5. Always organic soil amendments are preferred than inorganics once

Test II: Short Answer Questions

1. Mention the difference between macro and micro nutrient
2. Write the criteria of essentiality of plant nutrient.
3. Write the deference symptom of macro nutrient
4. What is mean by toxicity and deficiency of plant nutrient
5. What is nutrient mobility and its effect on plant growth

Operation Sheet 3

3.1 Identifications of nutrient deficiencies

A. Objectives

- To characterize deficiency symptoms of nitrogen, phosphorus, and potassium on selected plants.
- To observe and characterize abnormal symptoms of plants lacking nitrogen, phosphorus, or potassium.

B. Materials and Method

- Three species of plants (maize, bean, leaf lettuce) will be used. Maize and bean will be grown in perlite, whereas leaf lettuce will be grown hydroponically.
- Nutrient Solutions
- Five different solutions containing the complete combinations of macronutrients lacking one of the three macronutrients N, P, and K. All solutions will contain the standard concentrations of micronutrients (a modification of Hoagland Solution):

C. Procedures

1. Treatment 1 --- Complete fertilizer
2. Treatment 2 --- Lacking nitrogen (N)
3. Treatment 3 --- Lacking phosphorus (P)
4. Treatment 4 --- Lacking potassium (K)
5. Treatment 5 --- Lacking all macronutrients

Germinate seeds of the three species on inert medium (rock wool, perlite, sand, etc.) using deionized water. When the seedlings start developing true leaves, plant them in 6-inch plastic pots containing perlite (Maize and bean). For lettuce, place the seedlings on the a Styrofoam board which will float on top of a hydroponic solution contained in a plastic tub. Observe plant growth and development of deficiency symptoms for 8 weeks.

LG #4	LO #4 Preparing materials and equipment to apply fertilizers

Instruction Sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Considering for fertilizer application • Selecting and using fertilizer • Methods of fertilizer application • Selecting tools, equipment and machinery • Making pre-operational and safety checks on tools, equipment and machinery • Calibrating and adjusting tools, equipment and machinery • Handling and storing fertilizers safely This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Consideration for fertilizer application • Select and use fertilizer • Identify methods of fertilizer application • Select tools, equipment and machinery • Do Pre-operational and safety checks on tools, equipment and machinery • Calibrate and adjust tools, equipment and machinery • Handle and store fertilizers safely
Learning Instructions:

1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3. Read the information written in the information Sheets 4. Accomplish the Self-checks 5. Perform Operation Sheets 6. Do the “LAP test”

Information Sheet 4

4.1.Consideration for fertilizer application

The term "fertilizer material" means a commercial fertilizer containing one or more of the recognized plant nutrients, which is used primarily for its plant nutrient content. Fertilizers are derived from a wide variety of natural and manufactured materials and are sold in solid, liquid and gaseous form (anhydrous ammonia). These materials are designed for use or claimed to have value in promoting plant growth or increasing plant-available nutrient levels in soils.

4.2 Selecting and using fertilizer

Fertilizers are classified as two major types: Chemical fertilizers/ **Inorganic Fertilizers/** are generally synthetic or man-made compositions. Inorganic fertilizers are those that are manufactured with **pre-determined or declarable quantities of Nitrogen, Phosphorus and Potassium (NPK) nutrients**. These can be straight fertilizers with only one of the nutrients or compounds with a mixture of two or more nutrients.

Table 4.1 Common basic Fertilizer materials

Material	Analysis	Physical form	N (%)	P_2O_5(%)	K_2O(%)
Urea	46-0-0	solid (prills, granules, crystalline)	46	0	0
Ammonium nitrate	33-0-0	solid (prills or granules)	33	0	0
Ammonium sulphate	21-0-0 +24 S	solid (crystalline or granules)	21	0	0
Diammonium	18-46-0	solid, granule	18	46	0
Triple Super phosphate(TSP)	0-46-0	solid, granule	0	46	0
potassium chlorid (Muriate of potash)	0-0-60	solid, granule	0	0	46

Identifying the environmental implication of fertilizers

Nutrients added through fertilizers, manures and composts can have negative as well as positive effects on the environment depending on how poorly or properly these inputs are managed. The added nutrients may be absorbed by crops, immobilized by the soil or lost from the soil system. Depending on the nutrient and various conditions, these can be lost to the atmosphere by volatilization, lost through soil and water erosion, lost from the soil profile by leaching. Leached Nitrogen (N) can also be lost to the atmosphere through denitrification.

4.3 Methods of fertilizer application

There are different methods of fertilizer application depending on the kind of fertilizer material, the cropping system and equipment used by the produce. Fertilizer can be applied either in solid or in liquid form.

A. Application methods of fertilizer in solid forms include:

1. Broadcasting: It refers to even and uniform spreading of manure or fertilizer by hand over the entire surface of field while cultivation or after the seed is sown in standing crop. Suitable for crops with dense stand, the plant roots permeate the whole volume of the soil, large doses of fertilizers are applied and insoluble phosphate fertilizers such as rock phosphate are used.

Depend up on the time of application broadcasting can be divided in to two types.

i. **Broadcasting** at sowing or planting (**Basal application**)

The main objectives of broadcasting at sowing time are

- To uniformly distribute the fertilizer over the entire field and to mix it with soil
- To apply large quantities that can be safely applied at time of planting/sowing with seed cum fertilizer driller

ii. **Top dressing;** It is the spreading or broadcasting of fertilizers in standing crop (after emergence). Generally, N fertilizer are to dressed to the closely sown crops like paddy and wheat. e.g. Urea. The term side dressing refers the fertilizer placed beside the a row of crops (widely spaced) like maize or cotton. Care must be taken in top dressing that the fertilizer is not applied when the leaves are wet or it may burn or scorch the leaves.

2. **Placement**: It refers to the placement of fertilizers in soil at a specific place with or without reference to the position of the seed. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soil have a low level of fertility and to apply phosphatic and potassic fertilizer.

The most common methods of placement are as follows:

i. Plough sole placement

ii. Deep placement or sub-surface placement

iii. Localized placement or spot application

Localized placement or spot application includes:

- Contact placement or combined drilling or drill placement
- Side dressing
- Circular placement
- Band placement

B. Application methods of fertilizer in liquid forms includes

I. Starter solutions: It refers to the application of solution of N, *P2O5 and* K2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings.

II. Foliar application: It refers to the spraying of fertilizer solutions containing one or more nutrients on the foliage of growing plants. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them. The concentration of the spray solution has to be controlled otherwise serious damage may result due to scorching of the leaves. Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.

III. Application through irrigation water (Fertigation): It refers to the application of water soluble fertilizers through irrigation water. The nutrients are thus carried into the soil in solution.

IV. Injection into soil: Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types. Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions. Anhydrous ammonia must be placed in narrow furrows at a depth of 12-15 cm and covered immediately to prevent loss of ammonia.

V. Aerial application*:* In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands or in sugarcane fields etc.

4.4 Selecting tools, equipment and machinery

Application equipment and machinery may include backpack spray equipment, tractors and trailed or 3 point linkage spreaders, seeders, rippers and spray equipment, pumps and pump fittings, and irrigation systems set up for fertigation.

4.5 Pre-operational and safety checks on tools, equipment and machinery

Before operating any piece of equipment,

- Begin with a visual check of the work area.
  E.g. Checking any loose or missing parts of equipment
- Be seated and adjust the seat so you can easily reach all controls and see all gauges and indicator lights, then put on the seatbelt.
- Ensure the windows and mirrors are clean and not cracked so as to provide the operator clear visibility on all sides.
- Start the machine and check that all gauges are operational and that the lights, flashers, horn, and windshield wipers work.
- Check to ensure there is a fire extinguisher, first aid kit, and any tools or supplies that you will need to perform your task.

4.6 Calibrating and adjusting tools, equipment and machinery

Calibration is the process used to help that the equipment applies proper rates of the selected product. Calibration of the spreader depends on three things:

- The type of spreader being used
- The kind of fertilizer being used
- How fast the spreader is pushed or pulled over the area (operator speed)

Proper calibration is the key to successful use efficiency. Failure to calibrate equipment can result in ineffective application. Applying too little can result in poor crop growth and production. It is important to calibrate equipment on a regular basis to compensate for variation and equipment changes or wear with time.

The equipment will become worm or damaged with use and result in inaccurate output and spread pattern. It is wise to conduct regular servicing of spreader to ensure they are in good working order. Three items must be considered when calibrating a spreader. The first is the distribution pattern of the spreader. This represents the amount of area that will receive the fertilizer. The second is the product application rate, which is the amount of product applied per hectares. The third is the speed at which the equipment moves through the field. There are multiple factors affecting the distribution pattern of a rotary spreader, and some of them relate directly to the type of applied product. For this reason, it is recommended that the spreader be calibrated separately for each individual product to be applied. Spreader calibration should be checked more often when the spreader is used frequently.

4.7 Handling and storing fertilizers safely

If stored safely in a secure location, fertilizers pose little danger to ground water. Common sense suggests keeping fertilizer dry and away from activities that might rip open a bag or allow rain to enter a bulk container. In the event of such an accident, an impermeable (waterproof) floor, such as properly treated concrete, helps prevent fertilizer from seeping into the ground and leaching to ground water. A curb built around liquid-fertilizer storage areas prevent contaminates from spreading elsewhere. Store piles of dry bulk fertilizer on an impermeable surface under cover in a building. Treat dry fertilizer impregnated with a pesticide as a pesticide. Store under cover protected from rain.

4.7.1 Building a storage facility

Building a facility for fertilizer storage may be expensive, but this may be safer than trying to modify areas meant for other purposes. When building a fertilizer-storage facility, keep the following principles in mind:

- Locate the dry-storage building or liquid secondary containment down slope and at least 100 feet away from the well. The distance from the well should be greater if the site has sandy soil or limestone bedrock.
- In the event of a fire, contaminated water should drain to a confined area.

- The mixing and loading area should be close to your storage facility to minimize the distance that fertilizers are carried.
- The building foundation and secondary containment flow should be well drained and above the water table. The finished grade should be 3 inches below the storage-area flow and sloped away from the building to provide surface drainage.
- Provide pallets to keep bags off the floor. Store dry products separately from liquids to prevent wetting from spills.
- If you plan to store large bulk tanks, provide an area to confine 110% of the contents of the largest bulk container, plus the displaced volume of any other storage tanks.

4.7.2 Improving fertilizer storage and handling

A locked storage cabinet or building provides security. Preventing unauthorized use of fertilizer reduces the chance of accidental spills or theft. Provide signs or labels indicating that the cabinet or building is a fertilizer storage area. Labels on the outside of the building give firefighters important information about fertilizers during an emergency response to a fire or spill.

Self-check 4	Written test

Name:_________________________________ID___________Date___________

Direction: Answer the following question. Pay attention in each activity and try to answer to the point.

Test I: Multiple choice.

1. Which statement is not true about agricultural chemicals?

a) Nutrients added through fertilizers, manures and composts always have negative impact to the environment.

b) Leached Nitrogen (N) can also be lost to the atmosphere through denitrification.

c) Fertigation It refers to the application of water .

d) Broadcasting at sowing or planting of crops also called Basal application

2. Application methods of fertilizer in solid forms doesn't include one:

a) Broadcasting

b) Top dressing

c) Placement

d) Foliar application

3. In considering to build or located fertilizer storage facility ;

a) The mixing and loading area should be close to your storage facility

b) In the event of a fire, contaminated water should drain to a confined area.

c) Secondary containment flow should be well drained and above the water table.

d) all

Test II: Short Answer Questions

1. List and explain the application methods of solid fertilizers.

2. Discuss how to determine the level of nutrient in relation to plant growth.

3. Discus the positive environmental effects of commercial fertilizer.

LG #5	LO #5 Operate the fertigation process

Instruction Sheet

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

- Preparing fertigation materials
- Connecting, directing and calibrating injection or fertigation equipment
- Implementing startup sequence
- Calculating fertilizer concentration and mixed solution
- Operating, maintaining and monitoring fertigation process
- Application of fertigation
- Monitoring fertigation equipment
- Correcting, adjusting and implementing process and equipment

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Prepare fertigation materials
- Connect, directing and calibrating injection or fertigation equipment
- Implement start up sequence
- Calculate fertilizer concentration and mixed solution
- Operate, maintaining and monitoring fertigation process
- Apply fertigation
- Monitor fertigation equipment
- Correct, adjust and implement process and equipment

Learning Instructions:

7. Read the specific objectives of this Learning Guide. 8. Follow the instructions described below. 9. Read the information written in the information Sheets 10. Accomplish the Self-checks 11. Perform Operation Sheets 12. Do the “LAP test”

Information Sheet 5

5.1. Preparing fertigation materials

Fertigation - a modern agro-technique, provides an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency, minimizing fertilizer application and increasing return on the fertilizer invested. In fertigation, timing, amounts and concentration of fertilizers applied are easily controlled.

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

✓ **Equipment**

- In pressurized irrigation systems, the injected fertilizer solution has to be greater than that of the internal pressure.
- A filter to prevent dripper clogging by any solid particles from reaching the dripper.
- A back-flow preventing valve.

✓ **Fertilizers**

- Solubility of the fertilizers in the indigenous water source: irrigation water contains various chemical constituents some of which may interact with dissolved fertilizers with undesired effects.
- The degree of acidity of the fertilizer solution has to be considered in relation to its corrosiveness to the irrigation system components

Factors to be considered during fertigation includes:

- Soil Analysis: to determine soil nutrient availability and soil type. The soil analysis will assist in the development of a fertilization program.
- Irrigation System and Injector Pump: Drip Irrigation system is utilized for vegetable production. Injector pumps such as piston pump and Venturi type are recommended.
- Water Quality: Sediments in the water can plug the emitter s in drip hoses.
- Water Supply: Adequate supply of water demanded by the crop.
- Appropriate nutrient materials: It is essential that nutrients used for Fertigation are soluble.

5.2 Connecting and injection or fertigation equipment

Several techniques have been developed for applying fertilizers through the irrigation systems and many types of injectors are available on the market. There are two main techniques: the ordinary closed tank; and the injector pump. Both systems are operated by the system's water pressure. The injector pumps are mainly either Venturi type or piston pumps. The closed tanks are always installed on a bypass line, while the piston pumps can be installed either in-line or on a bypass line.

a) Fertilizer (closed) tank

This is a cylindrical, epoxy coated, pressurized metal tank, resistant to the system's pressure, and connected as a bypass to the supply pipe of the head control. It operates by differential pressure created by a partially closed valve, placed on the pipeline between the inlet and the outlet of the tank. Part of the flow is diverted to the tank entering at the bottom. It mixes with the fertilizer solution and the dilution is ejected into the system. The dilution ratio and the rate of injection are not constant. The concentration of fertilizer is high at the beginning and very low at the end of the operation.

b) Venturi type

This is based on the principle of the Venturi tube. A pressure difference is needed between the inlet and the outlet of the injector. Therefore, it is installed on a bypass arrangement placed on an open container with the fertilizer solution. The rate of injection is very sensitive to pressure variations, and small pressure regulators are sometimes needed for a constant ejection. Friction losses are approximately 1.0 bar. The injectors are made of plastic in sizes from to 2 inches and with injection rates of 40–2 000 litres/h. They are relatively cheap compared to other injectors.

c) Piston pump

This type of injector is powered by the water pressure of the system and can be installed directly on the supply line and not on a bypass line. The system's flow activates the pistons and the injector is operated, ejecting the fertilizer solution from a container, while maintaining a constant rate of injection. The rate varies from 9 to 2 500 litres/h depending on the pressure of the system and it can be adjusted by small regulators. Made of durable plastic material, these injectors are available in various models and sizes. They are more expensive than the Venturi-type injectors.

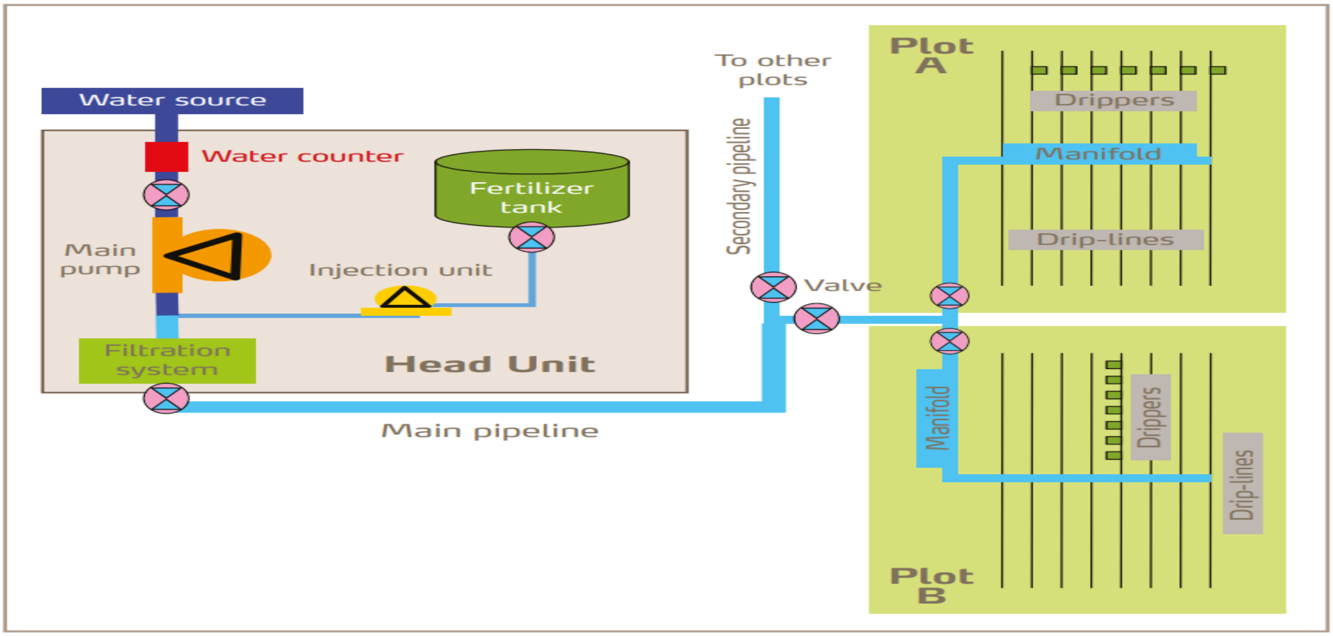


Figure 5.1 Basic fertigation system plan

5.3 Implementing start up sequence

It is important to run the system without fertilizer for a period prior to starting fertigation. In this way, pressure, flow rates and the area of the wetted bulb can be stabilized. The time needed to stabilize the system largely depends on its design capabilities.

This can be monitored by regular observation of pressure gauges. Post fertigation management is even more critical. Get it wrong and over flush the system and mobile nutrients such as nitrate and calcium can be leached out of the wetted bulb. Again, the time needed depends only on system layout. A simple way to calculate this is to measure how long it takes for the water and the injected solution to reach the plot furthest away from the pump by assessing changes in EC of the solution from the last dripper in the line.

Here are some steps that can be taken when implementing the start-up sequence of activities in fertigation:

1. **Install a fertilizer injector**: Install a fertilizer injector at the head control unit of the irrigation system, before the filter.
2. **Test the soil**: Have the soil tested 1–2 months prior to planting so that liming requirements might be addressed well in advance of planting. A soil test will also assess levels of available phosphorus, potassium, magnesium, sulfur, calcium, and micronutrients (minor elements) in the soil.
3. **Calculate planted acre**: Calculate the planted acreage, taking into account field surface and bed spacing. The University of Florida Vegetable Production Handbook includes information about the crop nutrient requirements for specific crops and growth stages.
4. **Select the correct fertilizer**: Fertilizers can be formulated in three ways: granular, dry soluble, or liquid. Either dry soluble or liquid forms may be used with drip irrigation.
5. **Determine crop nutrient requirements**: The crop nutrient requirements are usually determined on the basis of N, P2O5, or K2O pounds per acre for the entire crop cycle.
6. **Calculate injection rates**: Calculate injection rates based on crop nutrient requirements and stage of development. Recommendations are for daily injections, but growers may elect to inject daily, weekly, or twice weekly.
7. **Begin fertigation**: Start fertigation right after the system starts operation and finish a few minutes before the operation ends.

5.4 Calculating fertilizer concentration and mixed solution

Why mix fertilizer solution?

- Save money. Mixing nutrient solution is often less expensive than pre-made nutrient solutions.
- Transport and store fertilizer in larger quantities. Dry fertilizers take up less space than liquid fertilizer, weigh less, and can be stored safely for extended periods of time before being made into a liquid.
- Gain complete control over nutrient composition. By mixing a custom solution, you gain control over every macro- and micronutrient your plant will get.
- Ensure consistent, healthy plants. By correctly calculating your nutrient formula, you will help ensure a consistent growing environment for plants, leading to better results.

How to use the water soluble fertilizer calculator

Making hydroponic nutrients becomes much easier with the water soluble fertilizer calculator. All you need to do is to follow these instructions:

1. Enter the **N-P-K** numbers or the elemental percentages found under "guaranteed analysis" on the fertilizer's label.
2. Select the **desired element** for which you have a target concentration (in ppm or mmol per liter) in mind.
3. Enter the desired **concentration**, in either weight concentration (such as ppm) or molar concentration (such as mM or mmol/L).
4. Adjust the final **volume of diluted solution** to the size of your mixing container.
5. Record how much dry fertilizer is required to achieve your target concentration.

Eg. Calculating a nutrient solution recipe to achieve 200 ppm nitrogen

Let's say you have a **100-L water tank**, and want to calculate **how much fertilizer** to add to achieve **200 ppm nitrogen** (a common recommendation for many greenhouse crops). For this example, we'll be using a soluble fertilizer with **20-8-20** on the label. From the label, we know that our fertilizer is comprised of 20% nitrogen, 8% phosphate, and 20% potash by weight. Follow these steps to find the nutrient solution recipe:

1. Rewrite ppm as mg/L

You should know that **ppm is the same as mg/L** (mass of solute per volume of water). So, rewrite the units of the desired concentration of nitrogen:

nitrogen concentration (mg/L) = 200 ppm = 200 mg/L nitrogen

2. Determine final fertilizer concentration

Now we know how many mg/L of nitrogen we should add to water. To find how many mg/L of fertilizer to add, divide the nitrogen concentration by percent weight of N. The formula is:

fertilizer concentration (mg/L) = nitrogen concentration (mg/L) / percent weight

Percent weight is read from the label, and can be written as a decimal (20% = 0.2) or as 20 g N / 100 g fertilizer. Inserting our values, we get:

fertilizer concentration (mg/L) = 200 mg/L N / 0.2 = 1000 mg/L = 1 g/L

3. Calculate the weight of fertilizer to be added

You can now use the fertilizer concentration of **1 g/L** as a mixing ratio for any volume of water using the formula:

fertilizer (g) = fertilizer concentration (g/L) * water volume (L)

Since we are using a 100-L water tank, the calculation is as follows:

fertilizer (g) = 1 g/L of fertilizer * 100 L = 100 g

Therefore, we should add **100 g fertilizer** to 100 L of water to achieve 200 ppm N.

EXAMPLE – Fertigation with vegetables

- Crop: Tomatoes;
- Concentration of NPK fertilizers: 180-50-250;
- Type of fertilizers available: Ammonium nitrate (33.5-0-0) NH_4NO_3; Diammonium phosphate DAP (16-48- 0); $(NH_4)2HPO_4$; Potassium chloride (0-0-60) K_2O;
- System flow: 23 m^3/h;
- Irrigation dosage: 18 m^3;
- Duration of application: 1.5 hours.

Phosphate and potassium are given in oxides, therefore they are converted into P and K elements by multiplying by 0.4364 and 0.8302 respectively.

Calculation of the amounts of fertilizers needed in grams per cubic metre of water:

$$K = 250 \text{ x } 100 \div (60 \text{ x } 0.8302) = 0.502 \text{ kg } K_2O$$

$$P = 50 \text{ x } 100 \div (48 \text{ x } 0.4364) = 0.239 \text{ kg } (NH_4)2HPO_4$$

This amount also provides 38 g of N.

$$N = (180\text{-}38) \text{ x } 100 \div 33.5 = 0.424 \text{ kg } NH_4NO_3$$

Thus, for 18 m^3 of water, which is the irrigation dosage, the exact quantities are:

$$0.502 \text{ kg x } 18 = 9.036 \text{ kg } K_2O$$

$$0.239 \text{ kg x } 18 = 4.30 \text{ kg } (NH_4)2HPO_4$$

$$0.424 \text{ kg x } 18 = 7.63 \text{ kg } NH_4NO_3$$

The amount of water needed for the dilution of the above quantity of fertilizers is estimated by taking into account the solubility of the fertilizers:

9.036 kg K_2O *x* 3 litres	27.00 litres
4.30 kg Ca (H_2PO_4) *x* 2.5 litres	10.75 litres
7.63 kg NH_4NO_3 *x* 1 litre	7.63 litres
Minimum amount of water needed	45.00 litres

If the fertilizers are diluted in 60 litres of water and the duration of the irrigation is 1.5 h (1 h 30 min), then the injection rate should be about 40–45 litres/h in order to complete the fertigation in approximately 1 h 25 min.

Eg. Calculating the amount of fertilizer needed gram per cubic of water solution

5.5 Operating and monitoring fertigation process

5.5.1 Operating fertigation process

Operators of fertigation should have a high competency level and skill set. Operator skill is needed to detect and avoid:

- Change in nutrient availability; and
- Mineral precipitates from poor water quality or product solubility.

The operator must be able to calibrate and operate equipment, manage waste water discharge, salinization (electrical conductivity) of the solution requiring specialized treatment or disposal, and acidification of the (inert or soil) substrate.

The goal of a fertigation system is to apply the proper amount of a chemical at the appropriate time to the target area in a safe, effective, and uniform manner. However, not all irrigation systems are suitable for applying chemicals. An effective application system depends on uniformly applying the recommended amount of water throughout the application site. Furthermore, safety devices must be properly designed, installed, and maintained to prevent contaminating the source water and injection site. Take precautions to avoid surface runoff or deep infiltration, to minimize exposure from chemical residue, and to manage hazardous waste.

Figure 5.2 Typical fertigation system (dissolving ≥ mixing ≥ storing≥ pimping≥ selecting≥ fertigation)

5.5.2 Maintaining fertigation process

Growers need to regularly check irrigation systems to ensure all plants receive the water and nutrients they need. The two main checks carried out for this purpose are a pressure check and dripper discharge. Pressure tests should be carried out when every dripper is functioning properly. The main aim is to identify and maintain any unexpected falls in pressure within the system, such as broken pipes or poor connections. Drippers need a minimum pressure to operate effectively and discharge accurate amounts of water and nutrient. Normal operating pressures range between 1 to 4 bars.

5.5.3 Monitoring fertigation process

In order to take advantage of the agro-technical benefits of fertigation, very close monitoring of irrigation water, soil and growth media, drainage and crop is recommended.

I. Monitoring soil

For crops grown in soils, soil sampling and testing are essential tools to manage soil salinity and in determining nutrient supply. By means of soil tests, deviation between prevailing and optimum concentrations can be determined and corrective measures undertaken to restore required concentrations in the soil. Monitoring nutrient status in soils can be achieved by two approaches. The first involves soil sampling at a reference position in the root zone and extraction to determine soluble and sorbed nutrient concentrations in the soil. The second, for NO_3^- and Cl only, is to sample the soil solution directly by means of vacuum cups inserted permanently in the soil and to analyze the collected solution.

Frequency of sampling depends on the soil type, water quality and crop growth rate.

In orchards, sampling twice during the year can be enough but, if relatively high salinity water is used, sampling should be done every 3-4 weeks in order to monitor soil salinity and to decide about leaching dose applications. In intensive crops like vegetables, the soil should be sampled frequently (every 2-3 weeks) in order to monitor both the nutrient concentration in the soil and salinity, and eventually to correct the fertilization program or to leach accumulated salts.

II. Monitoring growth media

Knowledge of the nutritional status of all the components of a soilless culture system is important for two reasons:

- It is a means by which the grower can judge the success of the fertigation management practices; whether the planned fertilizer programme's objectives are followed in terms of nutrient availability; and
- It helps to diagnose nutrient deficiency and correct symptoms that may occur . The methods used in the analysis of available nutrients in growth media are based on the equilibration of a sample of the growth media with an extracting solution. Growth media samples are obtained from the root zone by taking a representative number of sub-samples and mixing them prior to their analysis. Growth media solution can be obtained by extracting a prescribed volume of the substrate in the laboratory or in the field by measuring nitrate-N, K and P using field kits.

III. Monitoring the quality of irrigation water

The objectives of sampling and analyzing the irrigation water are to:

- Evaluate its suitability for a specific crop, soil, irrigation method, filtration degree and other necessary chemical treatments;
- Determine salinity level and concentration of toxic elements in the water to assess their effects on crops;
- Determine sodium concentration and sodium absorption ratio (SAR) to assess the potential long-term effect on soil structure and water infiltration;
- Determine the nutritional value in order to take into account the nutrients in the water that is used in the fertigation programme.
- The main components of salinity are the cations calcium (Ca), magnesium (Mg) and sodium (Na), and the anions chloride (Cl-), sulfate (SO4-) and bicarbonate (HCO).
- Nitrate (NO) and potassium (K) are usually minor components of salinity. Boron (B) and other dissolved micronutrients are negligible in assessing the salinity of irrigation water.

Salinity is simply measured by determining the electrical conductivity (EC) of the water.

Sodicity or Na hazard of irrigation is related to soil dispersion, soil structure breakdown, potential for water infiltration problems, and accumulation of Na in plants

5.6 Application of fertigation

For each crop there are many fertilizer programs. Fertigation allows you to change your program during the growing season, adjusting it to suit fruit, flower, shoot and root development. A program should be developed on the basis of leaf and soil analysis and tailored to suit your actual crop requirements.

The majority of injectors available today can generally incorporate automatic operation by fitting pulse transmitters which convert injector pulses into electric signals. These signals then control injection of preset quantities or proportions relative to flow rate of the irrigation system.

Injection rates can also be controlled by flow regulators, chemically resistant ball valves or by electronic or hydraulic control units and computers.

If fertilizers are not completely dissolved and mixed prior to injection into the system, this may result in varying concentrations applied or blockages within the system.

Suitable anti-siphoning valves or non-return valves should be installed where necessary to prevent backflow or siphoning of water, fertilizer solution, chemical solution etc. into fertilizer tanks, irrigation supply, household supply, stock supply and so on.

Fertigation allows applying small amounts of fertilizer in each fertigation event, that contributes to high flexibility in fertigation frequency. Small and frequent applications of fertilizers reduce of potential for plant salt injury since the application of fertilizers can take into account the EC_w, the nutrients contained in the irrigation water, the type of fertilizer, etc.

The flexible and continuous application of plant nutrients, combined with water application, both corresponding to plant needs, increase their nutrient use efficiency, thus, decreasing the amounts of fertilizers (and other agro-chemicals) needed and consequently their leaching into groundwater and surface water resources.

Source: (https://youtu.be/tbv640XGz-w) Acessed on May 22,2023.

5.7 Monitoring fertigation equipment

During fertigation it is important to monitor:

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

The choice of fertigation equipment has to take into account both crop requirement and irrigation system capacity.

A. Gravity irrigation systems

This very simple method is only applicable to irrigation systems working at atmospheric pressure in which water flows in open channels. The fertilizer solution drips into the irrigation channel because the fertilizer tank is above the level of the channel.

B. Pressurized irrigation systems

Injection of the fertilizer consumes energy in order to overcome the internal pressure of the irrigation network. Fertilizer injection equipment is classified into three principal groups, according to the means employed to obtain the higher pressure for the fertilizer solution:

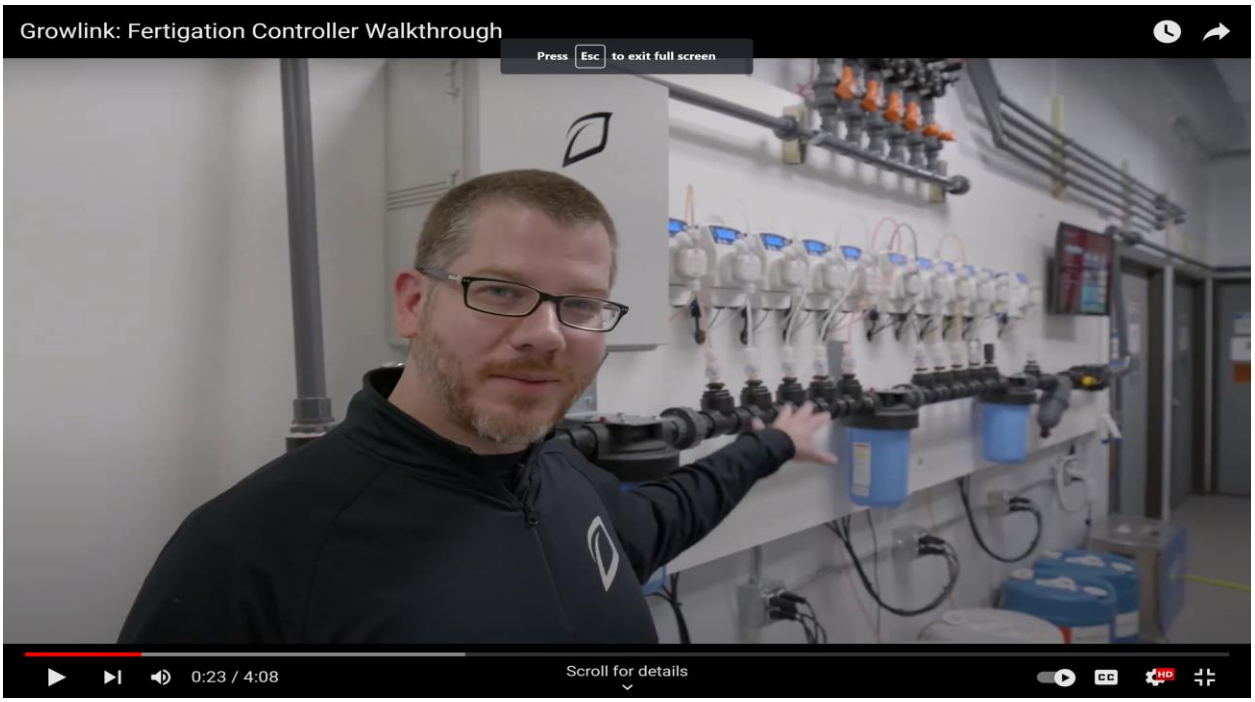
- Injection by a Venturi device: This is a unit that makes use of the Venturi suction principle by using the pressure induced by the flowing water to suck the fertilizer solution from the fertilizer tank into the irrigation line.
- Injection by differential pressure: This system utilizes an air tight pressure metal tank with anti-acid internal wall protection in which a pressure differential is created by a throttle valve that diverts part of the irrigation water into the tank. This is the only fertigation system that enables the use of both solid and liquid fertilizers.
- Injection by positive pressure: Injection pumps are able to raise the pressure of the liquid fertilizer from a stock solution tank at a predetermined ratio between fertilizer solution volumes to irrigation water volume, hence achieving a proportional distribution of nutrient in the irrigation water. The advantages of using injection pumps are the lack of pressure loss of the irrigation water, its accuracy and the ability to provide a determined concentration through the irrigation cycle. Two types of injectors are commonly used in fertigation: piston pumps and diaphragm pumps.

The most common power sources for fertigation pumps are:

- Hydraulic energy: The device uses the hydraulic pressure of the irrigation water to inject nutrient solution while the water used to propel it (approximately three times the volume of solution injected) is discharged. These pumps are suitable for fertigation in areas devoid of sources of electricity.
- Electric dosing pumps: The device activates the fertilizer pump. These are common in glasshouses and in areas where electricity is available and reliable.

5.8 Correcting, adjusting and implementing process and equipment

Corrective and adjustment measures should be taken in the implementation of fertigation process. However, it is important to monitor and adjust the delivery of fertilizers during the operation of the fertigation process to ensure that it is maintained. If any issues arise, corrections to the process and equipment adjustments should be implemented as necessary.



Sources: (https://www.youtube.com/watch?v=ESJdOgIkfh0) Acessed May 20, 2023.

Hydraulic or system operations

Pressure is too low

Possible causes:

- Pressure gauge is not functioning.
- Pressure gauge is located incorrectly in the system.
- Valves in the system are not open.
- Main pump has failed.
- Upstream main valve is closed or partially closed.
- Pressure regulators in the line have failed.
- Major leak in the system.
- Other plots are irrigating simultaneously or the valves in these other plots are malfunctioning.

Pressure too high

Possible causes:

- Check pressure gauge and connections -the outlet valve could be closed.
- Check all valves in the system including one-way and plot valves.
- Automatic plot valve system has failed - check electrical wires or hydraulic micro hoses.
- Filter system is clogged.
- Irrigation plot is too small for the system.
- Check devices for main pump - frequency variator malfunctioning.
- If pressure is increasing in the same plot every time - check the emitter to see if it is clogged.

System discharge too low

Possible causes:

- Check main pump.
- Check flow meter is functioning.
- Main plot valve is closed or partially closed.
- Air is in the system.
- Possible leak in the system.
- Emitters are clogged.
- Filters have collapsed.

By-pass tank still contains fertilizer at the end of the irrigation

Possible causes:

- Pressure differences across the pressure tank are too small – adjust valves if needed.
- Increase the flow into the tank. If it is already at its maximum setting - increase size of connection pipes, and inlet-outlet fittings.
- Irrigation time is too short to empty the by-pass tank.
- Fertilizer quantity is too high for the current system.

Injectors do not perform as planned

Possible causes:

- Check hydraulic conditions (pressure and water volume) in the injectors.
- For Venturi injectors, adjust either the pressure or system discharge changes at each operation - for each different plot.
- Check injection rate is properly adjusted.
- Valves of feeding tanks are closed or partially closed.
- Control filter for feeding tank is clogged.
- Injector has failed.
- Check that the discharge point at the head unit is not clogged.
- When working with high density solutions, injection rates should be adjusted accordingly compared to using straight liquid fertilizers.

Excessive or increased clogging problems at the emitters or inside the system

Possible causes:

- Check filtration equipment is functioning and not partially clogged, or broken.
- Filtration system is not suitable for the specific conditions.
- Check filter back-flush procedure (cleaning process).
- Check fertigation plan
  - Compatibility of fertilizer used.
  - Water quality.
  - Nutrient concentrations.
  - Interactions.
- Dissolving process for fertilizers used.
- Check for changes in fertilizer or water quality.
- Post-irrigation scheduling is not adequate or not carried out.
- Water treatment is needed due to changes or variations in water quality.
- Changes in the hydraulic properties of the system – e.g. irrigated area is larger than that originally planned for the system. This will reduce the velocity of water in the system leading to an increased settling of particles, which then accumulate and cause blockages.
- Leaks in the system can lead to soil or other material being introduced into the system – e.g. (suction of air and other material inside pipeline while working).

Head unit maintenance is essential

Figure 5.3 Troubleshooting tips in fertigation system.

Self-Check 5	Written Test

Name:___________________________________ID____________Date_______________

Direction: answer the following question. Pay attention in each activity and try to answer to the point

.

Test I: Write True or False

1. The choice of fertigation equipment does not depend on the crop requirement and irrigation system capacity
2. Gravity irrigation systems is a very simple method applicable to irrigation systems
3. Not all irrigation systems are suitable for applying chemicals.
4. Monitoring of fertigation process is done before Monitoring fertigation equipment
5. Salinity is simply measured by determining the electrical conductivity (EC) of the water.

Test II: Short Answer

1. Write list of process in monitoring fertigation process.
2. List & explain five troubleshooting tips in fertigation system
3. What is the benefit of monitoring quality of irrigation water in fertigation?

Operation Sheet

5.1 Implement startup fertigation process

A. Objectives

- To make sure irrigation equipment are ready for fertigation application

B. Materials and Method

- Fertigation injector
- 2. Irrigation system
- Fertilizer holding tank
- Water filtration system
- Sensors to monitor EC, pH, and temperature
- Solenoid valves for controlling water flow
- Irrigation timer or controller
- Flow meters to measure water usage and nutrient application
- Nutrient tanks or containers for storing fertilizers and nutrients
- Fertilizer pump for injecting fertilizer into the irrigation system.

C. Procedures

1. Check the fertilizer stock tank and ensure that there is enough fertilizer for the upcoming cycle. If not, refill the tank with the appropriate fertilizer solution.

2. Check the irrigation water source and ensure that it is clean and free of any debris that might clog the system.

3. Turn on the water supply to the irrigation system, but keep the valve to the fertigation system turned off.

4. Calibrate the fertilizer injection system to ensure that the ratio of water to fertilizer is correct. This can be done by running a few test cycles and measuring the amount of fertilizer injected, adjusting as necessary.

5. Start up the fertigation system by opening the valve between the irrigation system and the fertigation system.

6. Monitor the system for any leaks or malfunctions during operation. If there are any issues, stop the process and make necessary repairs.

7. Adjust the fertilizer injection rate as needed during the fertigation process to maintain proper fertilizer levels in the soil.

8. Once fertigation is complete, turn off both the water supply and the fertigation system

LAP Test 5

Name:_________________________________ID___________Date______________

Time started: ______________________ Time finished: _______________

Instructions: Given necessary templates, tools and materials you are required to perform the following task within 30 minutes. The project is expected from each student to do it.

Time started: ______________ Time finished: _______________

Task 1: Perform start up fertigation sequence

Request your teacher for evaluation and feedback

LG #6	LO #6 Complete Fertigation

Instruction Sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Flushing out injection equipment • Cleaning equipment • Managing waste • Reporting and recording fertigation activities This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Flushing out injection equipment • Cleaning equipment • Managing waste • Reporting and recording fertigation activities
Learning Instructions:
13. Read the specific objectives of this Learning Guide. 14. Follow the instructions described below. 15. Read the information written in the information Sheets 16. Accomplish the Self-checks 17. Perform Operation Sheets 18. Do the "LAP test"

Information Sheet 6

6.1 Flushing out injection equipment

The injection and distribution system should be purged after each application. This avoids precipitates from settling out of the solution and to lessen employee exposure from contact with residues on application equipment or other surfaces. In fact, many pesticide labels require that the injection and irrigation system be purged after the application.

Fertigation increases the quantity of nutrients present in an irrigation system and this can lead to increased bacteria, algae and slime in the system. These should be removed at regular intervals by injection of chlorine or acid through the system.

Chlorine injection should not be used while fertilizer is being injected into the system as the chlorine may tie up these nutrients making them unavailable to the plant.

Systems should always be flushed off nutrients before completion of irrigation. Before commencing a fertigation program, check fertilizer compatibilities and solubility.

6.2 Cleaning equipment

Proper care and maintenance will help retain precise application and prolong the life of spread manufacturer's direction cleaning and lubricating should be followed. With the shutter or gate wide open, remove all granules from the spreader at the end of each application. Then, the spreader should be thoroughly washed and allowed to dry. Hot water may help break loose fertilizer which is caked on. Finally, lubricate the spreader according to instruction. spreaders should be stored in a clean, dry place out of direct sunlight.

6.3 Managing waste

Containers must be properly cleaned before disposal. The best time to clean empty containers is during mixing and loading, because residue can be difficult to remove after it dries and is a source of human exposure. Refer to the pesticide label for rinsing instructions. If none are listed, triple rinse (or pressure rinse) the container, empty all rinse water into the spray tank, and apply to a labeled crop or site. Recycling cleaned empty containers is the best method of container disposal. Cleaned containers may also be disposed of in a sanitary landfill.

6.4 Recording and reporting fertigation activities

Once the plant nutrition program is developed and implemented, then it is important to see its profit concerning to production. If the program is sounded to be good and solve the objective met some goal ,then it is appreciated and document is kept for future analysis and use, but if not it will be incorporated to another plan.

Self-Check 6	Written Test

Name:________________________________ID__________Date_____________

Direction: Answer the following question. Pay attention in each activity and try to answer to the point

.

Test I: Write True or False

1. Irrigation systems should always be flushed of nutrients before completion of irrigation
2. Chemical containers must be properly cleaned before disposal
3. Not all irrigation systems are suitable for applying chemicals.
4. Before commencing a fertigation program, check fertilizer compatibilities and solubility.
5. Plant fertigation program is developed and implemented for profit concern.

Test II: Short Answer

1. What is the benefit of cleaning fertigation equipment?
2. List & explain the reason why we use chlorine as flushing chemical at the end of fertigation activity.
3. Why do we need to keep records of fertigation activities?

Reference Materials

(unpuplished modules);

- Kassahun, Gemechu &Yayeh, Agarfa Agricultural TVET College. Implement plant nutrition program and fertigation equipment TTLM Code: AGR CRP3TTLM08 0218.
- Derejaw A., Mizan Agricultural TVET College Implement plant nutrition program & fertigation equipment, level III.

<u>Books</u>

- Ayers, R.S. and W. Wescot. 1989.Water quality for agriculture, FAO Irrigation and Drainage paper 29 Rev. 1.
- Barber, SA. 1984. Soil nutrient availability: Mechanistic approach. John Wielly and Stone. NY. Boman, B.J. and E. W. Stover, 2002.
- Managing salinity in Florida citrus. University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS)

Web addresses

- https://youtu.be/tbv640XGz-w
- https://www.youtube.com/watch?v=ESJdOgIkfh0
- https://training.gov.au/Training/Details/AHCPCM305) 5/18/2023)
- https://agrolearner.com/crops-suitable-for-alkaline-soils/
- https://agrolearner.com/crops-suitable-for-alkaline-soils/ Accessed 5/19/2023.
- https://balchem.com/plant-nutrition/safety-data-sheets/
- https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/fertigation,Acessed 19/02, 2023)
- https://inspectorio.com/blog/4-ways-to-improve-corrective-and-preventive-actions,Accessed 18/05/2015)
- https://www.frontiersin.org/articles/10.3389/fenvs.2021.712831/full Accessed 5/19/2023.

- https://www.mdpi.com/2073-445X/10/12/1377, Review of Soil Salinity and Sodicity, Accessed 5/19/2023.
- (https://www.researchgate.net/publication/274700022_Soil_Stabilization_Using_Lime_Advantages_Disadvantages_and_Proposing_a_Potential_Alternative), Accessed 5/19/2023.
- https://www.geo.libretexts.org/Bookshelves/Soil_Science/The elusive role of soil quality in nutrient cycling: a review - Schröder - 2016 - Soil Use and Management - Wiley Online Library. Acessed 5/ 19/ 2013
- https://www.sciencedirect.com/topics/earth-and-planetary-sciences/soil-alkalinity
- https://www.eos.com/blog/soil-salinization/
- https://www.studocu.com/row/document/hawassa-university/irrigation-structures-ii/liii-lg-4-implement-plant-nutrition-program-and-fertigation-equipment/43110819
- https://edis.ifas.ufl.edu/publication/HS1206, , Yara Fertigation Manual 2020.pdf, accessed 18/05/ 2023)
- https://www.nsw.gov.au. Horticultural fertigation - techniques, equipment and management, Accessed 18/05, 2023.

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