Horticulture Crop Production - Level-IV

Based on March 2019, Version 2 Occupational standards

Module Title: Scheduling irrigations

LG Code: AGR HCP4 M14 LO (1-5) LG (66-70)

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Table of Contents

LG # 66	LO # 1- Monitor crop/plant water use

Instruction sheet

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

- Measuring or estimating water use
- Accumulating water as a soil water deficit in the root zone

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:

- Measure or estimate water use
- Accumulate water as a soil water deficit in the root zone

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". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet 1 - Measuring or estimating water use

1.1. Introduction

The irrigation schedule indicates how much irrigation water has to be given to the crop, and how often or when this water is given. The accurate determination of an irrigation schedule is a time-consuming and complicated process. At the beginning of the growing season, the amount of water given per irrigation application, also called the irrigation depth, is small and given frequently. This is due to the low evapotranspiration of the young plants and their shallow root depth. During the mid-season, the irrigation depth should be larger and given less frequently due to high evapotranspiration and maximum root depth. Thus, ideally, the irrigation depth and/or the irrigation interval (or frequency) vary with the crop development. Three simple methods to determine the irrigation schedule are: plant observation method, estimation method and simple calculation method.

Water use measurement is a key component to any conservation program. Meters and other measurement devices can be used as a tool in evaluating program effectiveness in terms of water usage changes. In addition, meters can provide a basis for billing with a rate structure such that customers pay for what is used and waste is discouraged.

1.2. Techniques for estimating water use

To achieve good irrigation management it is necessary to know the rate of plant water use. The techniques available include assessment of the plant, the soil and the weather. A very crude technique is to visually observe the conditions of the plant and recognize if it is stressed. The use of instruments allows more precise estimates to be made. The techniques include:-

a) Measure leaf temperature and determine the degree of water stress

If the leaves are cool during the hot part of the day (Figure 1), the plants do not suffer from water stress. However, if the leaves are warm, irrigation is needed. Special devices (infra-red thermometers) have been developed to measure the leaf temperature in relation to the air temperature. However, they must be calibrated for specific conditions before being used to determine the irrigation schedule.

Figure 1.1. Leaf temperature

b) Soil moisture measurements

The most accurate and reliable method of measuring soil moisture is to take a soil sample, weigh it, dry it and then weigh it again. This provides an accurate measure of the amount of water in the soil. This is called the gravimetric method. It is however labour intensive and time consuming. A wide range of instruments is available to monitor and measure the actual level and changes in soil moisture level. Soil moisture sensors can be broadly grouped according to those that measure the water content (mass or volume) and those, such as tensiometers that measure water tension. Careful consideration needs to be given to the characteristics and needs of the site prior to the selection of a soil moisture sensor.

c) Measurement of evaporation or calculating evaporation

A common technique is to estimate plant water requirements using climate data is by measurement of evaporation or by calculating evaporation from the climate parameters. The actual evaporation rate (Epan) is available from the Bureau of Meteorology or from a local (site specific) weather station. There are various techniques and mathematical expressions that can be used to estimate plant water use. The Crop Factor Method is the only one described in detail in this manual.

Self-check - 1	Written test

Name…………………………………………… ID……………………….. Date…….

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

Test I: Short Answer Questions

1. What is the indicator of irrigation schedule? (3pts)
2. What is the irrigation depth? (2pts)
3. Why the accurate determination of an irrigation schedule is a time-consuming and complicated process? (5pts)
4. List the simple methods of determining the irrigation schedule. (3pts)
5. Discuss the techniques of measuring water use. (5pts)

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

***Note:* Satisfactory rating - 10 points   Unsatisfactory - below 10 points**

Information Sheet 2 - Accumulating water as a soil water deficit in the root zone

2.1. Water use from the root zone

The root zone determines soil depth from which the crop can draw moisture. The active root zone is that part of the soil profile where the major portion of plant roots is located. Water below the active root zone is lost to deep percolation or is not immediately used by the plant. Root distribution in the root zone and water use from the root zone by a crop is not uniform in depth. This point is illustrated in Figure 2. About 70 percent of the crop's water requirement is taken up from the upper one-half of the root zone.

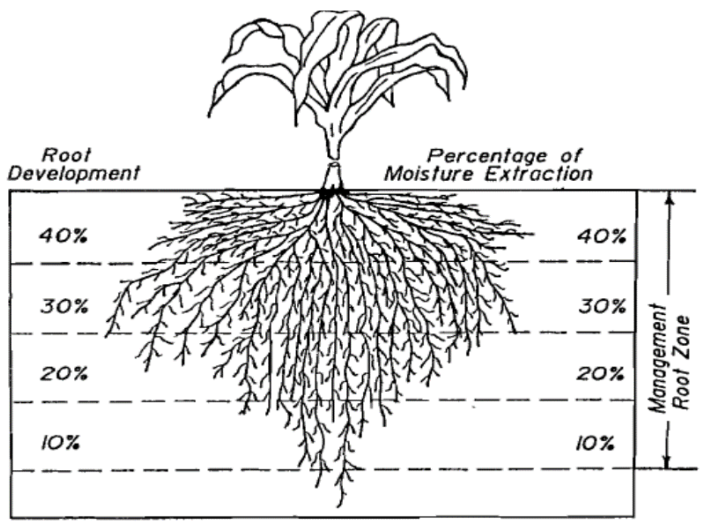

Fig. 2.1. Root development and percentage of moisture extraction from the active root

Rooting depths are determined by characteristics of the plant and soil. Rooting depths are often modified by soil compaction, stratification and moisture conditions. Roots of only a few plant species will penetrate dry soil, thus a layer of dry soil below the surface can restrict root growth. A high water table limits root growth. Fluctuating ground water may kill roots that have previously grown below the rising groundwater surface. High salt concentrations will also restrict root development.

2.2. Cumulative soil water deficit

The cumulative soil water deficit is obtained or calculated by adding all water deficits since the last irrigation. It is calculated by adding up the all of the water deficits since the last irrigation and subtracts the effective rainfall. (After an irrigation event the soil is saturated and crop water use is assumed to be zero).

The following example illustrates the moisture accounting method for tomatoes grown in January, in clay soil. For the sake of this exercise the Eto, Kc and rainfall were used. It is recommended to use a moisture balance sheet to keep a sound record for irrigation.

Step 1: Effective root depth (Dff) =0.55 meter

Step 2: For Clay loam, the total available water (TAW) is 180 mm/m.

Step 3: For tomatoes the depletion fraction (p) is 0.4.

Step 4: The readily available water. RAW= 0.4 * 180 =72

Step 5: The irrigation application depth (mm) = Dff * RAW = 0.55*72=39.6 (rounded 40 mm)

Step 6: The (ETo) was given in column A

Step 7: The evapo transpiration of the crop (ETc) is Eto *Kc. Calculated on column C

Step 8: Daily rainfall was given in column D. The effective rainfall (mm) was calculated in column E. In this example, the effective rainfall, during spring, summer and autumn periods calculated by subtract 5 mm from each of the daily rainfall totals. The main assumption is that rainfall of 5 mm or less to be non-significant (zero). In winter, all the rainfall is assumed to be effective.

Step 9: The cumulative soil water deficit was calculated by H=E+F-C on an accumulative basis.

Table 1. Example of irrigation scheduling

Table 8: Example of irrigation Scheduling

	A	B	C=A*B	D	E=D-5mm	F	H=E+F-C
Day	ETo (mm/day)	Crop coefficient (Kc)	Crop water use (Etc) (mm/day)	Rainfall (mm)	Effective rain (mm)	Net Irrigation application (mm)	Cumulative soil water deficit
1	7.6	0.85	6.5	0	0	0	-6.5
2	8.6	0.85	7.3	3.8	0	0	-13.8
3	8.6	0.85	7.3	0.4	0	0	-21.1
4	8.8	0.85	7.5	0	0	0	-28.8
5	7.1	0.85	6.0	0	0	0	-34.6
6	9.1	0.85	7.7	0	0	40	IRRIGATION
7	6.4	0.85	5.4	0	0	0	0
8	3.4	0.85	2.9	0	0	0	-2.9
9	6.2	0.85	5.3	6	1	0	-8.2
10	6.3	0.85	5.4	3.2	0	0	-13.6
11	4.3	0.85	3.7	4.6	0	0	-17.3
12	7.7	0.85	6.5	1.4	0	0	-23.8
13	8.7	0.85	7.4	17.8	12.8	0	-11.0
14	7.2	0.85	6.1	0	0	0	-17.1

2.3. The initiation of plant water deficit

Crop factors that affect ET are mainly associated with the dynamics of leaf-area development and senescence and the resistances to water flux developed in the soil-plant-atmosphere continuum (SPAC). When actual ET is close or equal to maximum ET, the environment exercises most of the control over ET. A reduction in actual ET below maximum ET is associated with the development of a gradient of potentials between the soil and the transpiring organs, leading towards a situation defined as plant water deficit. At the same time, the relative role of the plant in affecting ET becomes greater.

In the dry land agricultural domain where plant production is a major consideration the ultimate purpose is for the plant to deliver water from the soil to the leaves thus allowing sustained leaf gas exchange and the delay of leaf death.

Self-Check – 2	Written test

Name……………………………………………   ID………………………… Date…….

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

Test I: Short Answer Questions

1. What is the root zone? (2pts)
2. How root depth is characterized? (5pts)
3. How soil water deficit is determined? (5pts)

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

Note: **Satisfactory rating - 12 points   Unsatisfactory - below 12 points**

Operation Sheet 1- Measuring of soil moisture content

Purpose

- **To measure soil moisture content**

Materials

- Sensitive balance, spade, soil kits, hammer,

Procedure

1. Record sampling date, experiment, treatment, replicate, variate, etc. on the soil moisture spreadsheet.

2. Weigh out soils:
   A. for sieved composite soil samples, place soil moisture tin on the balance and tare the weight by zeroing the scale. Use a plastic spoon to subsample the composite sample and place 40-50 g of soil into the tared soil moisture tin. Record tin number and the exact fresh weight of soil (to nearest 0.01 g) in the tin on the soil moisture spreadsheet. Weights can be recorded directly from the scale to the spreadsheet using linking software. Cover tin with matching numbered lid.
   B. For soil core samples stored in moisture tins, moisture content is determined on the entire sample in the tin. Record tin number and the exact total weight of soil and tin, including the matching numbered lid, on the soil moisture spreadsheet. Weights can be recorded directly from the scale to the spreadsheet using linking software. Subtract the tare weight of the moisture tin and lid (weights are in a linked spreadsheet) from this value to determine the fresh weight of soil.

3. Remove lids and place tins into the oven. Oven dry soil to a constant weight: at least 24 hours at 105 degrees C for soil moisture only or 48 hours at 60 degrees C if C/N analysis is required.

4. When drying is complete, recap tins with numbered lids as they are removed from the oven. Allow to cool for 15 minutes.

5. Tare scale to zero. Place each tin containing soil, including the lid, on the balance and record total weight of tin + soil in spreadsheet. There is no need to weigh the tin+lid separately because these weights are already in the spreadsheet.
6. Dispose of soil unless needed for C/N analysis.

LAP TEST	Performance Test

Name________________________________ **ID…………….** **Date………**

Time started: ________________________ **Time finished:** ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 1 hour. The project is expected from each student to do it.

Task-1 Perform measuring of soil moisture content

LG # 67	LO # 2- Apply a measured amount of water

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics: • Predicting pre-determined deficit using a scheduling system • Applying Irrigation • Increasing water quantities to ensure dilution and transport of toxic solutes below the root zone. 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**: • Predict pre-determined deficit using a scheduling system • Apply Irrigation • Increase water quantities to ensure dilution and transport of toxic solutes below the root zone.
Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
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Information Sheet 1- Predicting pre-determined deficit using a scheduling system

1.1. Soil-moisture deficit

Soil-moisture deficit is the difference between the available water that soil can hold after gravitational drainage (field capacity) and the actual available water in the crop root zone. The grower should maintain the soil-moisture deficit less than a predetermined level to avoid reduction in yield and quality. The soil-moisture deficit needs to be estimated at the beginning and periodically throughout the growing season. Estimating the soil-moisture deficit at the beginning of the season is necessary to provide a reasonable initial condition estimate.

Periodic review of soil-moisture content during the growing season will verify water use on the water balance sheet and allow for adjustments on the balance sheet when the estimated soil-moisture deficit does not equal the actual soil-moisture deficit due to site specific differences. Soil-moisture deficit can be determined from information Water-holding capacity for various textural classes of soils and Feel method chart for estimating soil moisture). Ideally, soil samples should be taken in 6-inch increments to the depth used for water management purposes. The calculations made to estimate water-holding capacity and estimated soil-moisture deficit using the feel method. This method can be used to estimate the percentage of water remaining in a soil sample by observing how soil ribbons, forms a ball, or rolls between the fingers. If time for sampling is limited, one sample, taken at 1/3 the effective root zone depth, will give a representative soil moisture level if soil texture does not vary with depth.

Self-Check – 1	Written test

Name…………………………………………… ID……………………….. Date…….

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

Test I: Short Answer Questions (10pts)

1. Define soil-moisture deficit. (5pts)
2. When does soil-moisture deficit to be estimated? (5pts)

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

***Note:* Satisfactory rating - 10 points Unsatisfactory - below 10 points**

Information Sheet 2 - Applying Irrigation

2.1. Applying irrigation water

Only a portion of the water applied to the soil by the irrigation system is stored in the crop-root zone where it can be used. Under surface irrigation systems, that portion of the water that is not stored in the crop-root zone may be lost as runoff from the field or as deep percolation. Sprinkler irrigation losses result from evaporation and wind drift, and deep percolation resulting from non-uniform water application. Losses from drip systems are primarily due to evaporation and non-uniform water application. Application efficiency describes the fraction of applied water that is stored in the crop-root zone. Application efficiency will vary with the system, soil, and weather conditions. This factor is necessary to determine how much water to apply with an irrigation system to store the desired amount of water in the crop-root zone. For example, the calculation required to determine the amount of water that would need to be applied by a low pressure center-pivot sprinkler with an application efficiency of 85 percent to eliminate the soil-moisture deficit.

2.1. Classes of irrigation systems to apply water

There are three broad classes of irrigation systems:

A. Sprinkler irrigation

B. Drip irrigation

C. Surface irrigation

- Basin irrigation
- Furrow irrigation

The pressurized systems include sprinkler, trickle, and the array of similar systems in which water is conveyed to and distributed over the farmland through pressurized pipe networks. There are many individual system configurations identified by unique features (centre-pivot sprinkler systems). Gravity flow systems convey and distribute water at the field level by a free surface, overland flow regime. These surface irrigation methods are also subdivided according to configuration and operational characteristics. Irrigation by control of the drainage system, subirrigation, is not common but is interesting conceptually. Relatively large volumes of applied irrigation water percolate through the root zone and become a drainage or groundwater flow. By controlling the flow at critical points, it is possible to raise the level of the groundwater to within reach of the crop roots. These individual irrigation systems have a variety of advantages and particular applications which are beyond the scope of this paper. Suffice it to say that one should be familiar with each in order to satisfy best the needs of irrigation projects likely to be of interest during their formulation.

Irrigation systems are often designed to maximize efficiencies and minimize labour and capital requirements. The most effective management practices are dependent on the type of irrigation system and its design. For example, management can be influenced by the use of automation, the control of or the capture and reuse of runoff, field soil and topographical variations and the existence and location of flow measurement and water control structures. Questions that are common to all irrigation systems are when to irrigate, how much to apply, and can the efficiency be improved. A large number of considerations must be taken into account in the selection of an irrigation system. These will vary from location to location, crop to crop, year to year, and farmer to farmer. In general these considerations will include the compatibility of the system with other farm operations, economic feasibility, topographic and soil properties, crop characteristics, and social constraints.

A. Sprinkler irrigation

Water is pumped through a pipe system and then sprayed onto the crops through sprinkler heads.

Advantages

- Water conservation
- Soil conservation
- Efficient use of water
- Saving of labour
- Early seed germination
- Fertigations
- Soil amendments

- Frost protection
- Cooling of crops
- Higher productivity of crops

Table 2.1. Use of sprinklers for different horticultural crops

Crop Type	Crop Example
Flowers	Carnation, Jasmine, Marigold
Vegetables	Onion, Potato, Radish, Carrot
Spices	Cardamom

Table 2.2. Response of different crops to sprinkler irrigation

Crop	Water Saving (%)	Yield increase (%)
Cabbage	40	3
Cauliflower	35	12
Chillies	33	24
Garlic	28	6
Onion	33	23
Potato	46	4

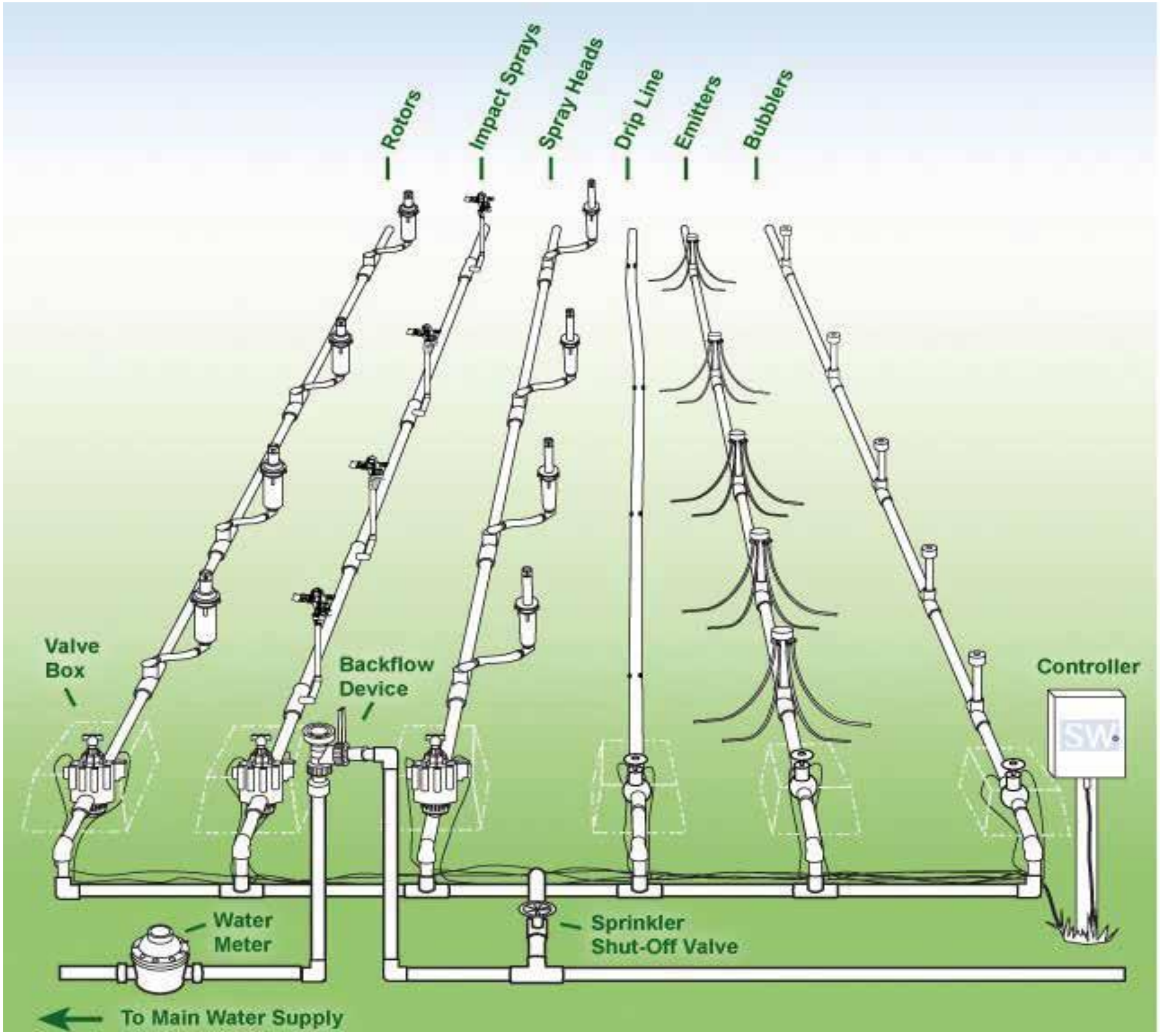

Figure 2.1. Lay out of sprinkler Irrigation system

Figure 2.2. Sprinkler Irrigation

B. Drip irrigation

Water is conveyed under pressure through a pipe system to the fields, from where it is discharged slowly or at a pre designed rate. The latter can be matched to the soil infiltration capacity through emitters or drippers that are located close to the root zone of the plants**.**

A typical drip irrigation system consists of the following components

- Pump unit
- Control unit
- Filtering unit
- Mainline and sub mainlines
- Laterals
- Emitters

Figure 2.3. Head control unit of drip irrigation

C) Surface irrigation

Surface irrigation is the application of water by gravity flow to the surface of the field.

- Either the entire field is flooded (Basin Irrigation) or the water is fed into small channels (furrows) or strips of land (borders).

Basin irrigation

Basins are flat areas of land, surrounded by low bunds.

- The bunds prevent the water from flowing to the adjacent fields
- The bunds prevent the water from flowing to the adjacent fields
- Basin irrigation is commonly used for rice grown on flat lands or in terraces on hill sides. Paddy grows best when its roots are submerged in water. Hence, basin irrigation is the best method to use for this kind of crop.
- Trees can also be grown in basins, where one tree is usually located in the middle of a small basin.

- In general, the basin method is suitable for crops that are no affected by standing in water for longer periods.
- Basin irrigation is suitable for many field crops.
- Crops suitable for basin irrigation include pastures, citrus, banana and crops that are broadcasted such as cereals and to some extent row crops such as tobacco
- Basin irrigation is generally not suited to crops, which cannot stand in wet or water logged conditions for periods longer than 24 hours; eg: potatoes, beet root and carrots
- The flatter the land surface, the easier it is to construct basins.
- It is also possible to construct basins on sloping land, even when the slope is quite steep. Level basins, called terraces, can be constructed like the steps of a staircase of a staircase
- Soils suitable for basin irrigation depend on the crop grown

Figure 2.4. Basin Irrigation

Furrows irrigation

- Furrows are small channels, which carry water down the land slope between the crop rows
- Water infiltrates into the soil as it moves along the slope
- The crop is usually grown on the ridges be- tween the furrows.
- This method is suitable for all row crops and for crops that cannot stand in water for long periods.
- Crops such as maize, sunflower, sugarcane, and soybean can be irrigated by furrow irrigation.
- Crops that would be damaged by inundation, such as tomatoes, vegetables, potatoes, beans; fruit trees like citrus and grape.

Figure 2.5. **Furrow Irrigation**

Self-Check – 2	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (10%)

1. What are the losses of applying water by drip irrigation?(3pts)
2. What Application efficiency? (2pts)
3. What are the losses of applying water by surface and sprinkler irrigation? (5pts)

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

Note: **Satisfactory rating – 10 points Unsatisfactory - below 10 points**

Information sheet 3 - Increasing water quantities

3.1. Increasing appropriate water quantities

All irrigation water contains some dissolved salts. The cannel water quantity is generally the same as the water of their parent's rivers, unless it is contaminated while passing through a salt affected area. The water quality of the area is generally good, except in Dry River water gets contaminated by pollution water from different sources.

Readily available water (RAW) is the water that a plant can easily extract from the soil. RAW is the soil moisture held between field capacity and a nominated refill point for unrestricted growth. In this range of soil moisture, plants are neither waterlogged nor water-stressed. Plant roots will continue to take water from the soil after the refill point is reached, but this water is not as readily available and the crop finds it difficult to extract. If the soil dries to the permanent wilting point, the plant can no longer remove any water from it: some water may still be present but is completely unavailable. The drier the soil, as shown by high tensiometer values, the more water needs to be added to bring the soil back to field capacity. These values are presented in table 5 as mm of moisture available per cm of soil depth. Increasing water quantity depending on crop water requirement is a crucial issue.

3.2. Water quality criteria

Of the several factors influencing water quality the generally accepted criteria for judging the quality are:

- Total salt contents
- Relative proportion of certain as expressed by sodium adsorption ratio
- Bicarbonates and boron contents

Generally increasing the amount of water to dilute the salt and toxicity is very important in toxic areas.

Self-Check – 3	Written test

Name………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (10pts)

1. Why the quality of dry river water is not good? (2pts)
2. What are the criteria for quality water? (5pts)
3. Why increasing the amount of water is very important in toxic areas? (3pts)

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

Note: **Satisfactory rating – 10 points Unsatisfactory - below 10 points**

Operation Sheet 1- Determining irrigation schedule

Purpose

- To determine the requirement of irrigation schedule

Procedure

Step 1. Determine the net and gross irrigation depth (d)

Step 2. Calculate the irrigation water need (IN) in mm, over the total growing season

Step 3. Calculate the number of irrigation applications over the total growing season

Step 4. Calculate the irrigation interval in days

Step 5. Finally, determine the irrigation schedule

LAP TEST	Performance Test

Name________________________________ **ID…………….** **Date………**

Time started: _________________________ **Time finished:** _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 1 hour. The project is expected from each student to do it.

Task-1 Perform determining of irrigation water requirement

LG # 68	LO # 3 - Assess efficacy of irrigation and repeat cycles of irrigation

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics: • Measuring effectiveness of irrigation application • Adjusting estimated soil moisture level in scheduling system • Recalibrating scheduling system • Repeating cycles of irrigation 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**: • Measure effectiveness of irrigation application • Adjust estimated soil moisture level in scheduling system • Recalibrate scheduling system • Repeat cycles of irrigation
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”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them. **4.** Accomplish the “Self-checks” which are placed following all information sheets. **5.** Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks). **6.** If you earned a satisfactory evaluation proceed to “Operation sheets **7.** Perform “the Learning activity performance test” which is placed following “Operation sheets” , **8.** If your performance is satisfactory proceed to the next learning guide, **9.** If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet 1- Measuring effectiveness of irrigation application

1.1. Irrigation efficiency

Irrigation efficiency is a quantitative term used to measure the effectiveness of irrigation water management. There are various definitions for irrigation efficiency, but it generally can be defined as the amount of water available to plants divided by the total amount of water delivered to an irrigation unit. Improved irrigation efficiency can lead to reductions in water and energy consumption, more effective nutrient use and disease management, improved water quality and erosion control, as well as increased yields. Additionally, water use in agriculture is often highly inefficient with only a fraction of the water diverted for agriculture effectively used for plant growth, with the rest drained or lost via evapo - transpiration.

With population growth and rising affluence, the need for food and thus agricultural water for irrigation is increasing. At the same time the quantity of water with a sufficient quality is declining. There is also an increasing demand to shift more of the water used in agriculture to higher-value urban and industrial uses. Thus, producing more with less is the only option.

Water efficiency in agriculture has been extensively researched for many years. Universally applicable solutions are however difficult to come by, particularly due to different contexts and high specificity of agricultural practices. But efficiency gains are often possible through suitable crop selection, proper irrigation scheduling, effective irrigation techniques, and using alternative sources of water for irrigation. It should be noted that increasing water efficiency often provides benefits that go far beyond reduced water use.

Self-Check – 1	Written test

Name…………………………………………… ID……………………….. Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers**.**

Test I: Choose the best answer (7%)

1. Define Irrigation efficiency. (2pts)
2. List the importance of improved irrigation efficiency. (5pts)

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

Note: **Satisfactory rating - 7 points Unsatisfactory - below 7 points**

Information Sheet 2 - Adjusting estimated soil moisture level in scheduling system

Water is a limited resource in semi-arid climate. The demand of water supply continues to rise with a rapidly expanding urban population. Crop irrigation is the largest water use in accounting for about 80 percent of annual diversions. Proper irrigation management has a positive effect on water use, plant health, and crop yields.

The use of soil moisture sensors helps growers with irrigation scheduling by providing information about when and how much to water. This provides for efficient use of water; enough to meet crop needs without applying excess or too little water. Excessive irrigation increases the cost of production from additional pumping costs and fertilizer lost to runoff and leaching. It can also decrease yields from waterlogging and leaching of soil nutrients. Excessive runoff can sometimes be harmful to the environment if fertilizers and pesticides moved to sensitive environments. Under-watering results in plant stress which can reduce yield and crop quality. This fact sheet introduces several soil water monitoring options that, when used correctly, can help growers avoid over and under watering. The use of soil moisture sensors requires an understanding of soil moisture depletion, available soil water, and irrigation application.

Self-Check – 2	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (17%)

1. How the use of soil moisture sensors help the grower. (3pts)
2. What is a limited resource in semi-arid areas? (2pts)
3. What are the requirements for the use of soil moisture sensors? (5pts)
4. Why excessive runoff can sometimes be harmful? (5pts)
5. What is the largest water use that accounting for about 80 percent of annual diversions? (2pts)

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

Note: **Satisfactory rating - 17 points Unsatisfactory - below 17 points**

Information Sheet 3 - Recalibrating scheduling system

3.1. Definition of Calibration

Calibration means adjustment or standardization of the accuracy of a measuring instrument, usually by comparison with a certified reference or standard. To adjust the final scheduling system recalibrating is very important.

All irrigation scheduling tools should be calibrated so they can be used the most effectively. Crop growth measurements are the simplest calibration method and can be done as soon as the crop starts to develop cane. Crop growth measurements will help determine the irrigation trigger point. At that point the reading on the scheduling tool is taken (for example, mini pan evaporation, tensiometer suction, etc). The tool has now been calibrated for that crop.

Equipment

- Tape measure or measuring stick (a piece of marked conduit works well).
- Bottle lids – for example, milk or juice bottle lids.
- Flagging tape.
- Recording sheet.

Site selection

- The crop should be near full canopy and actively growing.
- The monitoring site should be at least 5-8 rows from the edge and 2-3 m into the paddock.
- Select 25 main stalks, 12 stalks on one side and 13 on the other side. Mark each stalk with flagging tape and place the bottle lids at the base of the stalk (this provides a fixed base for measuring). Number each stalk so that there is a reference for recording.

Taking measurements

- Measure each day, making sure it is at the same time. Take the stalk and measure it from the ground to top visible dewlap (see photo). If the tape measure is hard to use, attach it to a piece of conduit or something similar.

- Record the stalk measurements (see example overleaf). Add these readings together and divide by 25 to give the average growth for the day.

Irrigation trigger points

- For a fully irrigated crop, the irrigation trigger point is when the average growth reduces to below 50% of the maximum recorded for two or more days.
- For a supplementary irrigated crop, the trigger point will depend on the amount of water available and the region.
- Crop growth can stall for a number of reasons, not just irrigation management. Weather conditions such as overcast days can have a major impact. Ideally stalk measurements should be done over more than one irrigation cycle.

Self-Check – 3	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (5%)

1. Define calibration. (2pts)

2. What is important to adjust the final scheduling system? (3pts)

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

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Information Sheet 4 - Repeating cycles of irrigation

The important decision as to when and how much water to apply to a growing crop must be repeatedly made throughout the growing season. Poor management resulting in either under or over irrigation can reduce crop yields, degrade crop quality, enhance the field environment for disease, increase pumping costs, and leach soluble nutrients from the root zone. A common reason for a controller to repeat a cycle is too many programmed start times. Only one start time per active schedule is required, a second start time will cycle the program an additional time.

4.1. Watering Cycles

You may notice that your watering schedule requires cycles. This is an important water conservation technique. Cycles per day means that you may need to break up your watering in a given day into smaller increments. For example, you may need to water for 20 minutes each day, but after ten minutes the water begins to run-off because of a slope or tight clay soil. This is when watering in cycles would be beneficial. In the example above it is better to water in two 10 minute cycles (each day) instead of 20 minutes all at once. This helps avoid wasteful run-off and water waste. Do not confuse cycling with irrigation frequency. Some people might be tempted to change their twice a week watering schedule to everyday to avoid run-off, this is a mistake. It is better to stay on your twice a week schedule (or whatever it might be) and break it up into cycles on the same day. Too frequent, shallow, watering causes unhealthy plants that are not drought resistant.

4.1. Irrigation interval or frequency

This is the number of days between two consecutive irrigations, $i = d \div ETc$, where d is the net depth of irrigation application (dose) in millimeters and ETc is the daily crop evapotranspiration in millimeters per day.

Self-Check – 4	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (10%)

1. Write the result of poor irrigation scheduling management. (3pts)
2. What is watering cycle? (3pts)
3. Define irrigation interval or frequency. (4pts)

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

Note: **Satisfactory rating – 10 points   Unsatisfactory - below 10 points**

LG # 69	LO # 4 - Record irrigation and scheduling parameters

Instruction sheet

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

- Recording each irrigation and significant rainfall event
- Estimating and recording drainage amount below root zone at each irrigation
- Recording system performance data

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**:

- Record each irrigation and significant rainfall event
- Estimate and recording drainage amount below root zone at each irrigation
- Record system performance data

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". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).

Information Sheet 1 - Recording each irrigation and significant rainfall event

Weather-based irrigation scheduling study was performed to evaluate the linkage between improved residential irrigation management and reduced dry-weather runoff. The irrigation scheduling must base on availability of rain fall in the area. If there is sufficient rain fall no need to irrigation the farm because over irrigation and under irrigation can also be a loss or damage to the crop.

1.1. Components of effective rainfall and their measurement

The evaluation of effective rainfall involves measuring rainfall and/or irrigation, losses toy surface run-off, percolation losses beyond the root zone and the soil moisture uptake by the crop for evapotranspiration. Information is needed on rooting depth of crop plants. Components are measured directly or indirectly and either individually or in an integrated way.

1.1.1. Rainfall and Irrigation

Total rainfall can be measured directly with rain gauges. Several types of recording and non-recording gauges are available. Irrigation applications can be measured with various types of notches, weirs, Parshall flumes, out-throat flumes and with direct recording water meters. The methods have been compiled and described by Dastane.

1.1.2. Surface Run-off

With efficient farm water management, surface run-off should be kept to a minimum. Only excess water should be removed by deep percolation and sub-surface drainage or by surface drainage. For a given field, run-off can be assessed with measuring flumes and water stage recorders or can be computed with formulae established for different conditions.

1.1.3. Rooting depth

For determining the water losses due to deep percolation and water uptake by a crop, the depth of rooting must first be known. The depth of root system varies from crop to crop and also from time to time during growth. The root system is influenced by several factors; too much wetness results in development of a shallow root system while drier soil water regimes encourage a deep one; soil texture and structure influence the depth of the root system to a great extent. Studies on rooting depths should, therefore, be made under existing and recommended cultural and irrigation practices on representative soils. The two most common methods of measuring the rooting depth are by excavation method and by studying soil moisture extraction patterns.

With the excavation method the roots are carefully dug from the soil, then cleaned, dried and weighed. The length and distribution in different layers is noted. The process is simple but laborious and careful handling is needed. But what is the effective root depth; is it the longest root or the mean root length? As a first approximation, the soil depth in which 90 percent (by weight) of the roots lie, can be taken as the effective root zone for irrigation purposes. However, several investigators have pointed out that the mass of roots and their activity do not have a simple linear relationship. There are generally more roots in the surface layer. Also, sometimes water extraction can be greater from the sub-soil than the surface soil. Water is extracted from a layer where it is readily available, provided there is a certain minimum root permeation in that layer. Soil moisture depletion can be determined by periodical soil sampling or by means of devices such as gypsum blocks or neutron probes. For irrigation purposes, the soil depth over which 80 percent of the total water intake takes place can toe regarded as the effective root zone of a crop. Since the root system is dynamic and continues to extend up to the flowering time, such studies are necessary at monthly or fortnightly.

1.1.4. Deep percolation losses

Deep percolation losses can be determined directly by using lysimeters or indirectly by computation of soil characteristics including soil water content, soil moisture tension and soil permeability. With the direct method, a representative and undisturbed soil column is enclosed in a large container or a tank fitted with an outlet at the bottom from which excess water can be drained into a measuring cylinder; this is the so-called drainage lysimeter. The lysimeter needs to be surrounded by a large cropped area. The method has been widely used since all the components of water gains and water losses can be measured from which a water balance can be obtained.

1.1.5. Evapotranspiration

The level of evapotranspiration is controlled mainly by three factors, namely, plant characteristics, extent of ground cover and stage of growth; water availability in the soil; and meteorological parameters or the evaporative demand. Maximum or potential evapotranspiration (ETp) occurs when the soil water is non-limiting and the crop is in an active stage of growth with full ground cover; the level of ETp for a given plant species is then mainly governed by the meteorological conditions.

Actual evapotranspiration (ETa), which is also sometimes called consumptive water use, is the actual quantity of water lost during crop growth by evaporation from land surface and by transpiration by plants.

Self-Check – 1	Written test

Name…………………………………………… ID………………………… Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions (5%)

1. Why weather-based irrigation scheduling study is performed? (5pts)

2. List the components of rainfall and discuss each of them. (5pts)

3. How deep percolation losses can be determined directly? (5pts)

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

Note: **Satisfactory rating – 5 points Unsatisfactory - below 5 points**

Information Sheet 2 - Estimating and recording drainage amount below root zone at each irrigation

Drainage of agricultural lands is intended to control and manage soil moisture in the crop root zone, provide for improved soil conditions, and improve plant root development. In cases where the water table impinges upon the root zone, water table control is an essential element of irrigation water management. However, installation of subsurface drainage should only be considered when good irrigation water management, good nutrient management, and good pesticide management are being conducted. Further, impacts to wetlands, wildlife habitat, and water quality must be thoroughly investigated, and relevant federal, state, and local laws fully considered prior to installation of drainage practices.

Drainage increases water infiltration, which reduces soil erosion and also allows application of excess water to keep salts leached below the root zone. Drainage also provides more available soil moisture and plant food by increasing the depth of the root zone. Subsurface drainage may concentrate soluble nutrients in irrigated return flows. Properly installed subsurface drainage systems can be used successfully as a supplemental source of irrigation water if the water is of good quality.

Root depth

This is the soil depth from which the plants take nearly 80 percent of their water needs, mostly from the upper part where the root system is denser. The rooting depths depend on the plant physiology, the type of soil, and the water availability (kind of irrigation). Indicative. In general, vegetables (beans, tomatoes, potatoes, onions, peanuts, cucumbers, etc.) are shallow rooted, about 50–60 cm; fruit trees, cotton and some other plants have medium root depths, 80–120 cm.

Drainage excess water

Depth and frequency of rain and the peak drainage discharge are closely related. The rate at which excess water must be removed from the soil is termed 'drainage co-efficient', which is expressed in mm per day or in m^3 /sec/ha. This value is based on rainfall characteristics and on the excess water tolerance of the crop.

For a given situation consideration may need to be given to surface run-off, deep percolation losses from rainfall, seepage of irrigation canals and underground flows from adjacent areas. The absolute as well as relative contributions from the different sources vary in time as well as in quantity. Often they are also interdependent. Only the rainfall component in drainage flows is considered in the following section.

In simple terms, the sum of the daily rainfall minus consumptive use rate plus or minus the soil storage change, is the drainage need. In humid regions, the amount of precipitation will have a direct relationship to the quantity of water to be drained. In arid and semi-arid regions, the annual surface run-off from rain may range from about 0 to 200 mm while the seepage, percolation and leaching in irrigation schemes may range from 200 to 2 000 mm. Losses from irrigation systems may be of great significance. Precipitation is of little consequence and can most often be ignored in computing drainage discharges.

Self-Check – 2	Written test

Name…………………………………………… ID………………………… Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions (12%)

1. Discuss the importance of drainage? (10pts)

2. What is the essential element of irrigation water management? (2pts)

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

***Note:* Satisfactory rating – 12 points Unsatisfactory - below 12 points**

Information Sheet 3 - Recording system performance data

3.1. Performance data

Performance data may include**:** - pressures, flow rates, distribution uniformity, depth of irrigation, and soil moisture at root zone. Data may be recorded on graphs and charts on paper and/or electronically.

3.2. Calculating distribution uniformity

The most common measure of distribution uniformity is the Low Quarter Distribution Uniformity. This is a measure of the average of the lowest quarter of catchment samples, divided by the average of all catchment samples. Higher distribution uniformity indicates a better performing irrigation system. If all catchment samples are equal, the distribution uniformity is 100%. There is no universal value of distribution uniformity for satisfactory system performance, but generally a value greater than 70% is considered acceptable. The lower the distribution uniformity, the less efficient the distribution, which means more water must be applied to meet the minimum requirement.

$$\text{DU (of lower quarter)} = \frac{\text{Avg Catch in lower quarter}}{\text{Avg Catch Overall}}$$

$$\text{DU} = \frac{\text{\_\_\_\_\_\_\_\_ mL}}{\text{\_\_\_\_\_\_\_\_ mL}}$$

DISTRIBUTION UNIFORMITY (DU) = ________

Distribution uniformity is useful when determining the total watering requirement during irrigation scheduling.

For example: An irrigator does not want to apply less than one inch of water to an area. If the distribution uniformity is 75%, total amount of water to be applied would be the desired amount of water divided by the distribution uniformity (1 inch / 0.75). In this case, the required irrigation would be 1.33 inches of water. Keep in mind that applying at least 1 inch of water to the entire area will result in over irrigating some areas.

Self-Check – 3	Written test

Name…………………………………………… ID……………………….. Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions (10 %)

1. When distribution uniformity is useful? (2pts)

2. What does it mean by the lower distribution uniformity? (5pts)

3. What is the most common measure of distribution uniformity? (3pts)

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

***Note:* Satisfactory rating – 10 points Unsatisfactory - below 10 points**

LG # 70	LO # 5 - Plan for extremes of weather

Instruction sheet

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

- Modifying estimated deficits to prolonged saturation following heavy rainfall
- Altering shift areas and application rates to suit appropriate irrigation schedules
- Implementing strategies prioritizing of plants/crops and intermittent irrigation

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**:

- Modify estimated deficits to prolonged saturation following heavy rainfall
- Alter shift areas and application rates to suit appropriate irrigation schedules
- Implement strategies prioritizing of plants/crops and intermittent irrigation

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". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).

Information Sheet 1 - Modifying estimated deficits to prolonged saturation following heavy rainfall

1.1. Soil-moisture deficit

Soil-moisture deficit is the difference between the available water that soil can hold after gravitational drainage (field capacity) and the actual available water in the crop root zone. The grower should maintain the soil-moisture deficit less than a predetermined level to avoid reduction in yield and quality. The soil-moisture deficit needs to be estimated at the beginning and periodically throughout the growing season. Estimating the soil-moisture deficit at the beginning of the season is necessary to provide a reasonable initial condition estimate. Periodic review of soil-moisture content during the growing season will verify water use on the water balance sheet and allow for adjustments on the balance sheet when the estimated soil-moisture deficit does not equal the actual soil-moisture deficit due to site specific differences.

Soil-moisture deficit can be determined from information water-holding capacity for various textural classes of soils and feel method chart for estimating soil moisture. Ideally, soil samples should be taken in 6-inch increments to the depth used for water management purposes. The calculations made to estimate water-holding capacity and estimated soil-moisture deficit using the feel method. This method can be used to estimate the percentage of water remaining in a soil sample by observing how soil ribbons, forms a ball, or rolls between the fingers. If time for sampling is limited, one sample, taken at 1/3 the effective root zone depth, will give a representative soil moisture level if soil texture does not vary with depth.

1.2. Evapo-transpiration

Evapo-transpiration (ET) is defined as the quantity of moisture that is both transpired by the plant and evaporated from the soil and plant surfaces. All of the weather-based products reviewed operate on the principle of scheduling irrigation as a function of weather conditions. Most of the products use real time or historic weather data to schedule irrigation based on evapo transpiration (ET), which is a function of weather conditions and plant type.

Self-Check – 1	Written test

Name…………………………………………… ID………………………… Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions (10%)

1. Define evapo-transpiration. (5pts)

2. What is soil-moisture deficit? (5pts)

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

Note: **Satisfactory rating – 10 points   Unsatisfactory - below 10 points**

Information Sheet 2 - Altering shift areas and application rates to suit appropriate irrigation schedules

Critical to any irrigation management approach is an accurate estimate of the amount of water applied to a field. Frost/freezing damage occurs when ice formed in side plant cells. Protection is a heat balance process. A risks always remains that serve weather conditions will exceeds the ability of any frost protection schemes to fully protect a crop. Most success full programs for protecting crops from frost damage are a mix of passive and active measures.

a. Passive frost protection include site selection, use of cold tolerant crop variety, delaying planting in the spring.
b. Active frost protection include conservation of heat, addition of heat, mixing in warmer air, using cover crop, fossil fueled heaters, wind machines and etc.

Self-Check – 2	Written test

Name…………………………………………… ID……………………… Date…….
Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions (13%)

1. What is critical to any irrigation management approach? (2pts)

2. What is a heat balance process? (2pts)

3. What is the success full programs for protecting crops from frost damage? (5pts)

4. Define passive frost protection. (2pts)

5. Define active frost protection. (2pts)

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

Note: **Satisfactory rating – 13 points   Unsatisfactory - below 13 points**

Information Sheet 3 - Implementing strategies prioritizing of plants/crops and intermittent irrigation

3.1. Horticultural crops sensitive to water shortages

If good management practices are ensured higher water use efficiency can be achieved with deficit irrigation for crops that are less sensitive to stress such as cassava, sugar beet. Different irrigation strategies, soils and irrigation systems would require different amounts of irrigation to produce maximum ET and yield. The best use of irrigation water would be that all water is utilized by the crop for evapo transpiration. An optimal yield is usually obtained with maximum actual evapo transpiration with high level of crop water availability. Irrigating to achieve maximum yield and consequently crop evapo transpiration ETc is not the most efficient use of irrigation water**.** If the water supply is adequate, irrigation scheduling can be monitored such that the soil moisture content is maintained through-out the seasons in the roots zone depth at levels which do not hamper the crop growth. Any restriction in supply of water is likely to induce a decrease in crop yield. Water deficits are unavoidable in some periods of the growing season when available supply is limited.

Table 2: Sensitivity of various horticultural crops to water shortage

Sensitivity	**Low**	**Low-Medium**	**Medium-High**	**High**
Crops	Cassava	Citrus	Cabbage	Banana
		Grape	Onion	Potato
		Sugar beet	Pepper	
			Tomato	
			Water melon	

Irrigation scheduling becomes difficult because irrigation decisions need to be decided on the crops sensitivity to water deficits in different periods of its growth. It is necessary to take into account the stage of growth when plants are most sensitive to water shortage. Each crop has certain stages at which if there is shortage of water, yield is drastically reduced. When there is shortage of water, it is better to take care of critical stages first to obtain increased water use efficiency. It requires an evaluation of alternative irrigation schedules and choosing the schedule which maximizes yields for the given level of water supply. Regulated deficit irrigation is one of the options to maximize water use efficiency for higher yields per unit of irrigation water applied.

Deficit irrigation practices differ from conventional water supplying practices, wherein improvement over crop water which uses dual crop coefficient approach separating evaporation and transpiration. The dual crop coefficient approach gives a better estimation of daily crop evapo transpiration because it separately considers soil evaporation and crop transpiration. This approach allows one to plan irrigation schedules properly, especially in the case of crops that do not completely cover the soil, where evaporation from the soil surface may be substantial.

Table 3. Periods sensitive to water shortages for some horticultural crops

Crop	**Sensitive period**
Banana	Throughout
Cabbage	Head enlargement and ripening
Citrus	Flowering and fruit setting more than fruit enlargement
Grape	Vegetative period and flowering more than fruit filling
Groundnut	Flowering and pod setting
Onion	Bulb enlargement
Pepper	Throughout
Pineapple	Vegetative period

Self-Check – 3	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions (10 %)

1. Write at least three horticultural crops that can grow in water stress areas? (2pts)

2. Why the dual crop coefficient approach gives a better estimation of daily crop evapo transpiration? (3pts)

3. Discuss the periods sensitive to water shortages for some horticultural crops by giving example. (5pts)

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

Note: **Satisfactory rating – 10 points Unsatisfactory - below 10 points**

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This Teaching, Training and Learning Materials (TTLM) was developed on December, 2020 at Bishoftu.

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