E-COBSI

Expansion of COmmunity-Based Smallholder Irrigation Development Project

Module 5: Water Management, Operation & Maintenance

Keywords for better irrigation farming:

"Rotational Irrigation"

"Maintenance of Irrigation Facilities"

1. Rotational Irrigation

(1) Distribution Method of Irrigation Water

- Simultaneous distribution

In case of plentiful water in furrow, you can use simultaneous distribution method!

Plentiful water

Limited water

- Rotational distribution

Rotational Irrigation is common and very useful to distribute limited irrigation water!

Recommended

a) Simultaneous Distribution

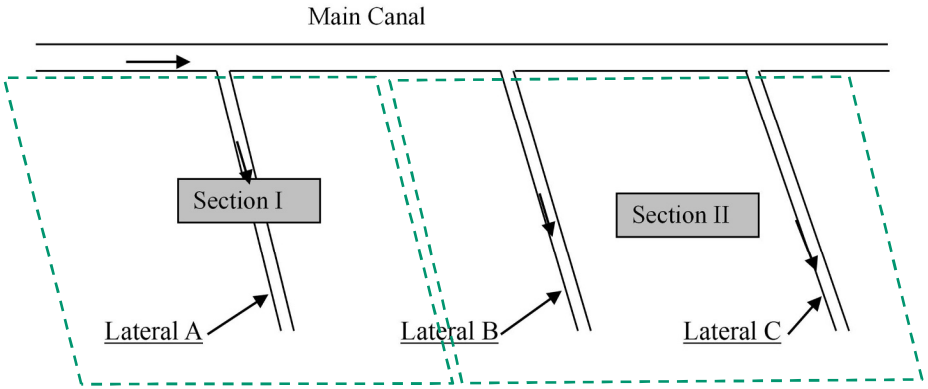
- This method involves simultaneous supply of water to all the canals.

b) Rotational Distribution

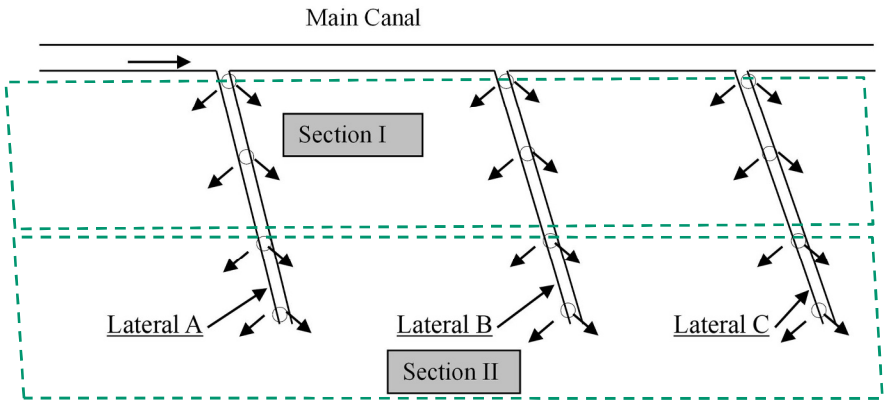
- Rotational distribution is practiced by rotating the supply of water to different areas.

Rotation by Section in Main Canal

Advantage of rotation irrigation: fair water distribution, not only upstream farmers but also downstream farmers can enjoy irrigation farming!

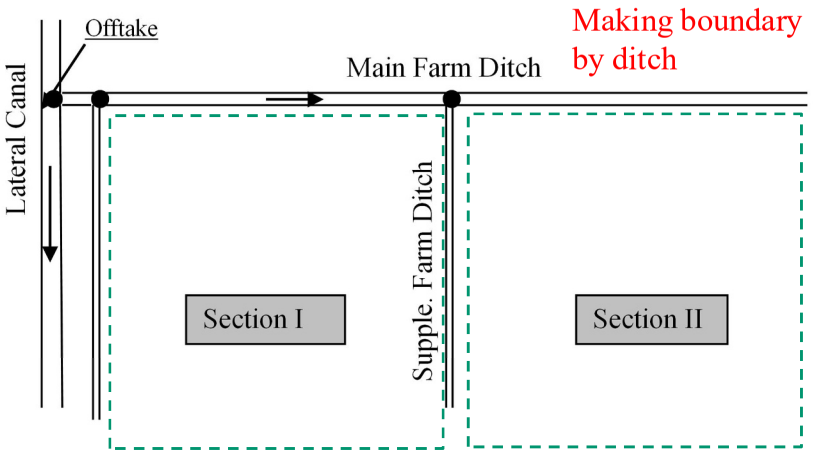


Rotation by Section or Turnouts in Lateral/Feeder Canals



Advantage of rotation irrigation: fair water distribution, not only upstream farmers but also downstream farmers can enjoy irrigation farming!

Rotation by Section in Farm Ditch



(2) Irrigation interval days

Irrigation interval is very important to practice rotation irrigation! How to decide the interval on field level by ordinal farmers,,,,,,, Just checking the soil color!!

・Farmers should observe the proper interval day
- degree of dryness at a depth of **15cm from surface**
- how many days will soil color change after irrigation?
  (from wet condition to dry condition)

・Farmers will decide the irrigation interval days for irrigation site by irrigation group.

[Recommended irrigation interval days by E-COBSI]
・Sandy soil → 2 to 3-day irrigation intervals
・Clayey soil → 3 to 5-day irrigation intervals

Important!

Without irrigation, crops are going die

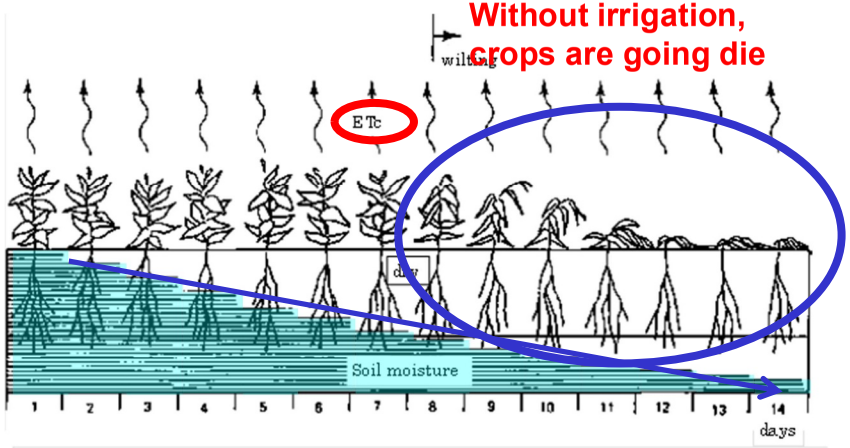


Figure 5-7 with no rainfall and no irrigation
Source: Irrigation Water Management Training Manual No.4 "Irrigation Scheduling". FAO, 1989

By irrigating, Crop can grow appropriately.
But, no need everyday irrigation.
If you irrigate everyday, roots grow only ground surface, means the power to absorb the water and nutrition get weakened.

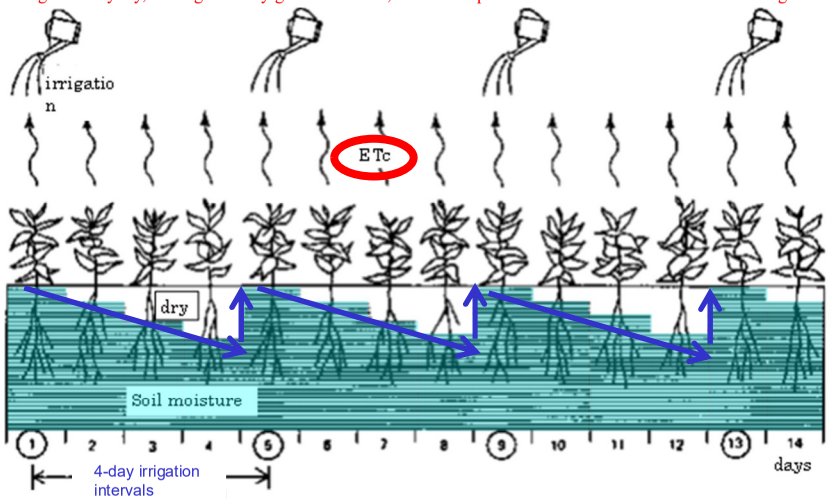


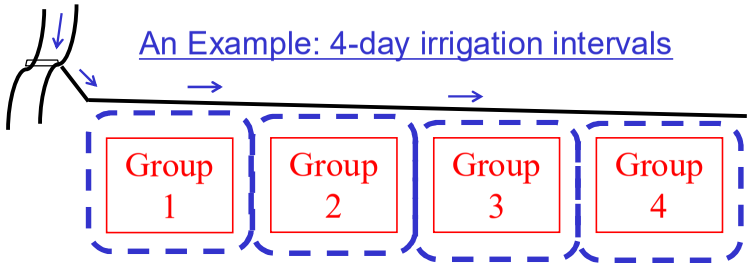
Figure 5-8 with irrigation
Source: Irrigation Water Management Training Manual No.4 "Irrigation Scheduling". FAO, 1989

An Example: 4-day irrigation intervals

(3) Group for Rotational Irrigation

- 3-day irrigation intervals → Making three groups
- 4-day irrigation intervals → Making Four groups

Important!



Group \ Days	1	2	3	4	5	6	7	8	9	10
First day group	✓	-	-	-	✓	-	-	-	✓	-
Second day group	-	✓	-	-	-	✓	-	-	-	✓
Third day group	-	-	✓	-	-	-	✓	-	-	-
Fourth day group	-	-	-	✓	-	-	-	✓	-	-

✓: Irrigation day

(4) Quantity of Irrigation water

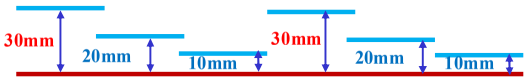
Important!

- 3-day irrigation intervals
  → 3 days' worth of water requirement at once
- 4-day irrigation intervals
  → 4 days' worth of water requirement at once

- As water requirement is **approx.10mm/day**, in case of 3-day irrigation intervals, 3 days' worth of water requirement is 30mm (3 cm). In case of 4-day irrigation intervals, 4 days' worth of water requirement is 40mm (4 cm).
- Size of plot_1m x 5m (3-day irrigation intervals):
  1m x 5m x 10mm x 3 days = 0.15m3(150 L)
  (approx. water requirement at once for 1m x 5m)

An Example

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Day-1	Day-2	Day-3	Day-4	Day-5	Day-6
Irrigation	No Water	No Water	Irrigation	No Water	No Water



2.Maintenance of Irrigation Facilities

Irrigation facilities function well so long as they are kept in good condition. If no attention is paid to the facilities, various problems may arise.

Obvious thing,,,,

In order to prevent major problems such as damages and leakages of weir and furrow, the weir and furrow should be regularly inspected throughout the irrigation season.

When problems will be found, damaged parts and obstacles should be recovered and removed immediately.

(1) Items to be inspected

Irrigation Facilities	Items to be inspected	Points to be checked
Simple and Permanent weir	Weir body, Intake and Bank	Damage, Crack, Leakage, Sediment and weed, etc.
Furrow (Earthen and lined furrow)	Bed, Bank, Road crossing, Gully crossing and inlet of plots	Damage, Crack, Leakage, Sediment, Erosion, Weed and Fallen leaves, etc.

(2) Conditions to be maintained

Damaged simple weir shall be repaired.

Sedimentation sands at weir shall be removed.

Weeds in furrow shall be removed.

A lot of leaves in furrow shall be removed.

(3) Maintenance Works

Every year before irrigation season, Simple/Permanent Weir and Furrow (Canal) shall be checked and maintained properly.

Awareness creation activity on terms of maintenance is needed for farmers!

1) Simple Weir

During operation of the irrigated farming, the diversion weir should be maintained properly.

If a hole is found at the weir, immediately stop it by sealing with clay soil. This process will restore the weir its former good shape, as the hole will be a source of weakness whereby the structure can fail.

If simple weir was damaged seriously, it shall be reconstructed.

2) Permanent Weir

As per fixed type weir of stone masonry, no routine maintenance work is usually required.

Inspection around the weir should be carried out periodically and after every flood and every year before starting dry season irrigation.

Following items should be inspected,

- **Damaged part of stone masonry.**
- **Scouring at downstream of the weir.**
- **Sediment at upstream.**
- **Scouring at both side abutments.**

2) Permanent Weir

Damaged part of stone masonry should be repaired with mortar.

Scoured part at downstream of the weir should be protected by stone pitching.

Scoured side abutment should be replaced with stone masonry.

In the case that sediment accumulated to inflow to canal, it should be removed.

3) Furrow (Canal)

Stream water usually contains certain amount of suspended particulars, causing sedimentation in the canal.

Eroded soil loss from furrow also gets into furrow, resulting in the sedimentation in the furrow.

Maintenance work for furrow should be done at least once before the irrigation season starts.

Maintenance works required for the canal are; cleaning, weeding, de-silting, re-shaping, and also minor repairs as described next page;

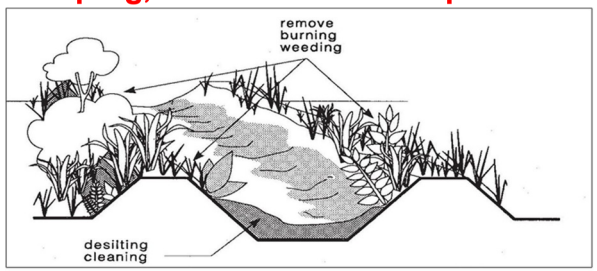


Figure 3-1 Weeding, cleaning and de-silting
Source: Irrigation water Management Training Manual No.7, FAO, 1992

3) Furrow (Canal)

a) Earth canal

- **Crossing sections by people and animals (livestock) along the canal should be strengthened by hard compaction or lined with stones, bricks or masonry.**
- **Holes/cracks should be filled with sticky clay soil, soil of anthill or mortar, and eroded sections should be rebuilt to the original shape.**

b) Brick lined canal (for permanent weir)

- **Cracks and water leaking point should be repaired with mortar.**

(4) Maintenance Check List for Simple and Permanent Weir

Item	Frequency	Point to be checked / Finding	Action
1. Simple Weir - Weir body - Intake - Bank	After flood / Weekly	Damage / Water leakage	Little --> Repair (Add grasses and soil) Much --> Reconstruction
	Weekly	Water leakage	
	Weekly	Sediment, leaves and trash	Remove sediment, leaves and trash
	Weekly	Weeds	Remove weeds
2. Permanent Weir - Weir body - Intake - Bank	After flood / Annually	Crack / Damage	Little --> Repair by using mortar (Cement), Much --> Repair by using stone masonry (Mortar and stone) "TSB officers will advise how to repair"
	Annually	Water leakage	
	Annually	Riverbed scouring at downstream	Add rubble stone at downstream
	Monthly	Sediment, leaves and trash	Remove sediment, leaves and trash
	Monthly	Weeds	Remove weeds

*Permanent weir: In case of flooding, stop log of intake should be installed to prevent major problems such as damage and erosion of furrow.

(5) Maintenance Check List for Furrow (Canal)

Item	Frequency	Point to be checked / Finding	Action
Furrow - Earthen furrow - Lined furrow - Road crossing - Gully crossing - Inlet of plot	Monthly	Sediment, leaves and trash	Remove sediment, leaves and trash
	Monthly	Weeds	Remove weeds
	Monthly	Damage, erosion	Little --> Repair and Close the hole by using clayey soil, Much --> Reconstruct embankment by using clayey soil with compaction
	Fortnightly	Water leakage	
[Lined furrow]	Monthly	Crack / damage	Little --> Repair by using mortar (cement), Much --> Repair by using stone masonry (mortar and stone) "TSB officers will advise how to repair"
	Fortnightly	Water leakage	

*Mortar Mixing

1. Standard mixing proportion of cement: sand is;
   1:3 in weight (dry)
2. Measure one 50kg pocket of Cement and six buckets (20liter) of sand.
   If the sand is dry, 20 liter of water is poured and mixed first. Then additional water is sprayed and mixed to the proper consistency.

Photos of the Maintenance works

Damaged simple weir is repaired.

Weeds in furrow are removing.

Sedimentation sands in furrow are removing.

(6) Repair for leakage in furrow (Canal)

Water may also be lost for irrigation by leakage. This water does not seep, but flows through larger openings in the furrow (canal) bed or sides.

Leaks can develop in several ways:

- By rat or termite holes in a watercourse bed or sides;
- Eroded and washed bank;
- Small tunnels started by seepage water in a badly compacted or sandy section of a bank;
- Seepage around structures, leading to severe leakages;

(6) Repair for leakage in furrow (canal)

Leaks should be repaired immediately after they have been observed.

Figures 3A shows that quick action can save time and money. In Figure 3A, a small hole in a furrow is repaired soon after it has been observed.

In Figure 3B, no attention has been paid to the leak, and, after some weeks, part of the bank has been washed away by the continuously leaking water. More time and money is needed to repair the furrow in this case.

(6) Repair for leakage in furrow

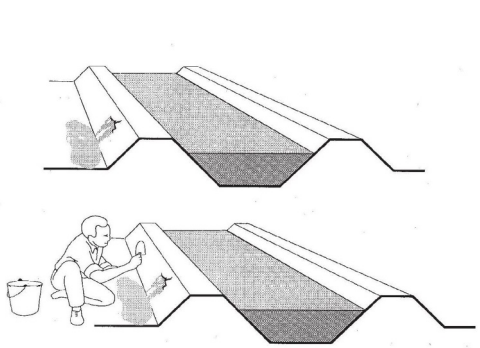


Figure 3A crack in a bank is repaired soon after it has been observed
Source: Irrigation Water Management Training Manual No.7, FAO, 1992

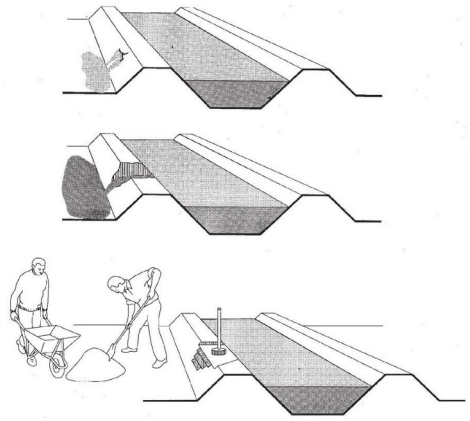
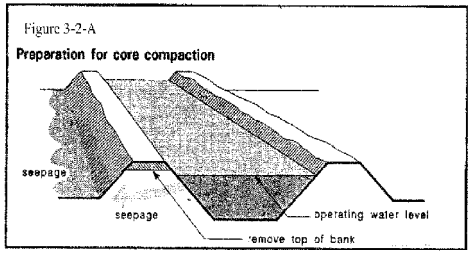
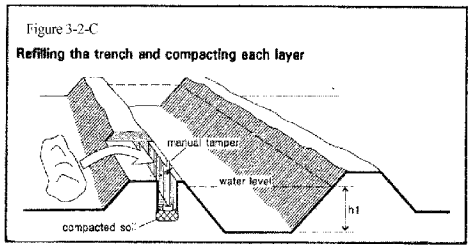


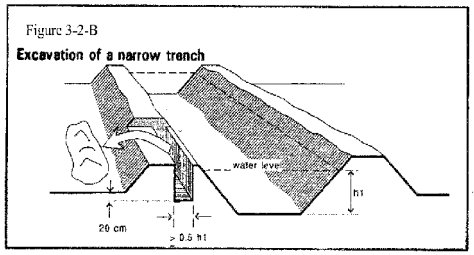
Figure 3B Delayed repair of a leakage
Source: Irrigation Water Management Training Manual No.7, FAO, 1992

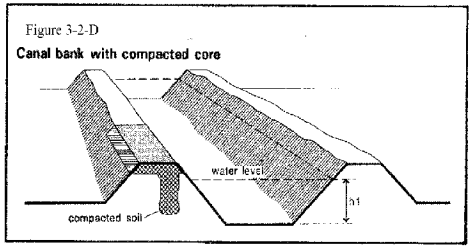
(6) Repair for leakage in furrow (e.g.: compaction)

The embankment is first excavated by digging and then replaced with soil in layers, compacting each layer.









Source: Irrigation water Management Training Manual No.7, FAO, 1992

(6) Repair for leakage in furrow (e.g.: double-line)

May, 2018

(7) Maintenance Cost

Cray soil, sand for mixing mortar and manpower are normally free of charge. Only cement and some tools should be purchased.

It is recommended that farmer group will buy one or two pockets of cement every year. If they can collect money as water fee, they will be able to repair the furrow strongly.

For permanent weir, farmer group will buy another one or two pockets of cement every year. Total of cement is three or four pockets of cement.

Collection of Water User's Fee!

- Target of 1 pocket of cement: K100 (Simple weir)
- Target of 2 pockets of cement: K200 (Simple weir)
- Target of 3 pockets of cement: K300 (Permanent weir)
- Target of 4 pockets of cement: K400 (Permanent weir)

CEOs should understand "2. Maintenance of Irrigation Facilities" and explain it to farmer.

*Strengthening Farmers' Group

[Process for collection of water Fee at Permanent Weir Site]

Strengthening Farmers' Group

1) Selection of Board member

2) Making Farmers List

- Sample of Farmers List is shown in next slide

3) Making By-law

- Samples of By-law will be distributed

Upgrading

Simple Weir

Permanent Weir

4) Opening of Bank Account

Maintenance Work of Irrigation infrastructures

5) Collection of Water Fee

6) Repairing of Permanent Weir and Canal

- Material purchase by farmers
- Technical support by TSB

[Sample of Farmers List]

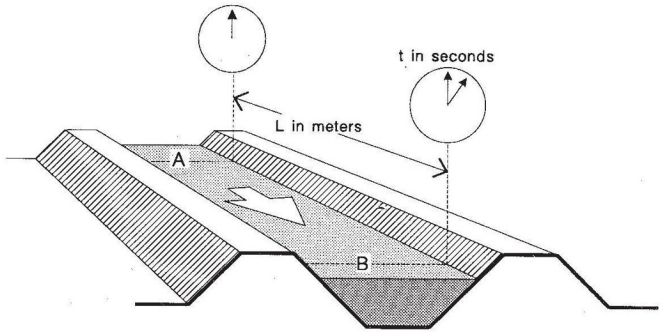
No.	Name	Position	Phone number
1.	xxxxx xxxxxxxx	Chairman	xxxxxxxxxxxxx
2.	Yyyy yyyyyy	Vice chairman	
3.	Zzzzz zzzzzz	Secretary	
4.		Vice Secretary	
5.		Treasurer	
6.		Member	
7.		Member	
8.		Member	
9.		Member	
10.		Member	
11.		Member	
12.		Member	
13.		Member	

3.Practice on the field

3.1 Estimation of Discharge at the Intake

Discharges in intake should be measured for estimation of irrigable area.

(1) Measuring Flow Velocity



- Select a straight section of the beginning of furrow at least 1.0 meters long. The shape of the furrow along this section should be as uniform as possible.
- Place the floating object (stem of weed or leaf) on the center line of the furrow at least 0.5 m upstream of point A, and start the stopwatch when the object reaches point A.
- Stop the stopwatch when the floating object reaches point B, and record the time in seconds.
- At least three (3) times in order to determine the average time necessary for the object to travel from point A to point B.
- The object should not touch the watercourse embankment during the trial.

If the object touch anyplace in the furrow, the trial should be canceled!
Do it one more time please!!

- If length of measurement is 1.0m, time is 1.8s, 2.0s and 2.2s,

Average time: (1.8s + 2.0s + 2.2s)/3=2.0s

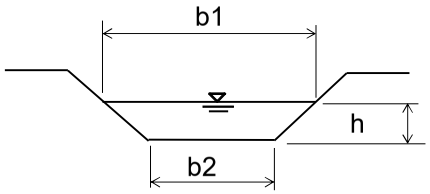
Average velocity (surface): 1.0m/2.0s = 0.50 m/s

(2) Measuring Furrow section

- Measure the following in the selected furrow section:

- the furrow bed width, b1
- the surface water width, b2
- the water depth, h

- The cross-section within the selected portion of the furrow will usually not be regular, and so b, a1 and h1 need to be measured in several places to obtain an average value.



Area = 0.5 x (b1 + b2) x h

Where,
b1=1.1m, b2=0.6m, h=0.25m:
Area = 0.5 x (1.1 + 0.6) x 0.25
=0.21 m^2

(3) Calculation of discharge

- Calculate the discharge, Q, in the furrow
- Q = 0.8 x V x A (m^3/s) = 0.8 x 1000 x V x A (lit/s)

Velocity on the water surface is faster than underwater. Need to convert to mean velocity!

Where,
0.8 : coefficient (surface velocity to mean velocity)
V: 0.50 m/s (average velocity (surface))
A: 0.21 m^2 (area)

Q = 0.8 x 0.50 x 0.21 = 0.084 (m^3/s) = 84 (lit/s)

Q=0.8 x V x A

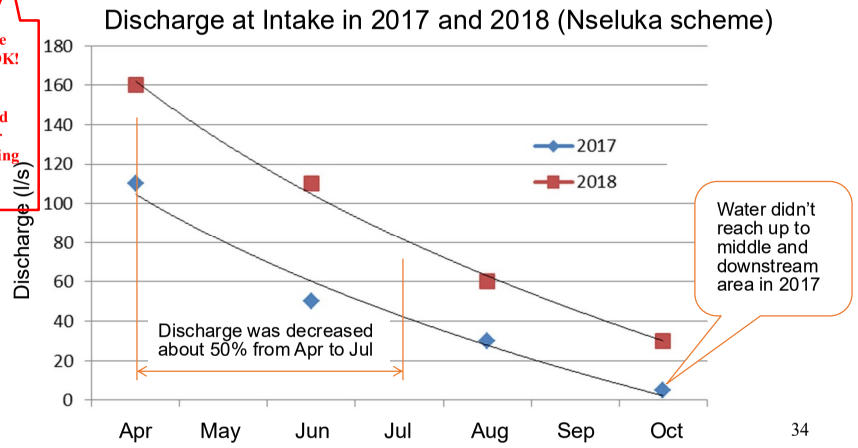
CEOs should understand "3.Practice on the field" of this document up to here and explain to farmer.
More technical slide are prepared at next slide as "advanced information" for irrigation officers of TSB.

*** Advanced information**

3.2 Discharge in the canal will be decreased through cultivation period

Farmers should consider that discharge at intake will be decreased, when they will plan farming schedule and irrigated area. It is recommended to measure discharge at intake monthly and make a chart like following chart.

Just One day is OK! You can assume the trend of water decreasing in a dry season.



Maintenance Check List for Simple Weir / Permanent Weir by farmers			
Item	Frequency	Point to be checked / Finding	Action
1. Simple Weir - Weir body - Intake - Bank	After flood / Weekly	Damage / Water leakage	Little --> Repair (Add grasses and soil) Much --> Reconstruction
	Weekly	Water leakage	
	Weekly	Sediment, leaves and trash	Remove sediment, leaves and trash
	Weekly	Weeds	Remove weeds
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	Annually	Water leakage	
	Annually	Riverbed scouring at downstream	Add rubble stone at downstream
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Maintenance Check List for Furrow by Farmers			
Item	Frequency	Point to be checked / Finding	Action
Furrow - Earthen furrow - Lined furrow - Road crossing - Gully crossing - Inlet of plot	Monthly	Sediment, leaves and trash	Remove sediment, leaves and trash
	Monthly	Weeds	Remove weeds
	Monthly	Damage, erosion	Little --> Repair and Close the hole by using clayey soil, Much --> Reconstruct embankment by using clayey soil with compaction
	Fortnightly	Water leakage	
[Lined furrow]	Monthly	Crack / damage	Little --> Repair by using mortar (cement), Much --> Repair by using stone masonry (mortar and stone) "TSB officers will advise how to repair"
	Fortnightly	Water leakage	

E-COBSI

Expansion of COmmunity-Based Smallholder Irrigation Development Project

Module 5:
On-farm Irrigation Method (Gravity, Sunken bed, and Furrow)

Introduction

There are several ways of applying water to crops. The principal methods are:

- Surface irrigation
- Sprinkler irrigation
- Trickle irrigation

Objectives

- To apply adequate amount of water to meet crop needs;
- Apply water uniformly
- Avoid unnecessary wastage of water and ensure there are no long term problems on the farm (e.g. soil erosion, salinity).

Types of Surface Irrigation:

- Basin
- Furrow
- Border
- Flooding

Criteria for the selection of surface irrigation method

- Land slope
- Soil type (infiltration rate)
- Field shape
- Crops
- Labour

Important Points for the On-Farm Irrigation

- Direction of the ridge (contour)
- Size (height) of the ridge
- Amount/Frequency of watering
- Timing of watering (morning)

Direction of the Ridge

Which is better?

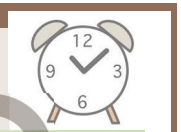
Size of the Ridge

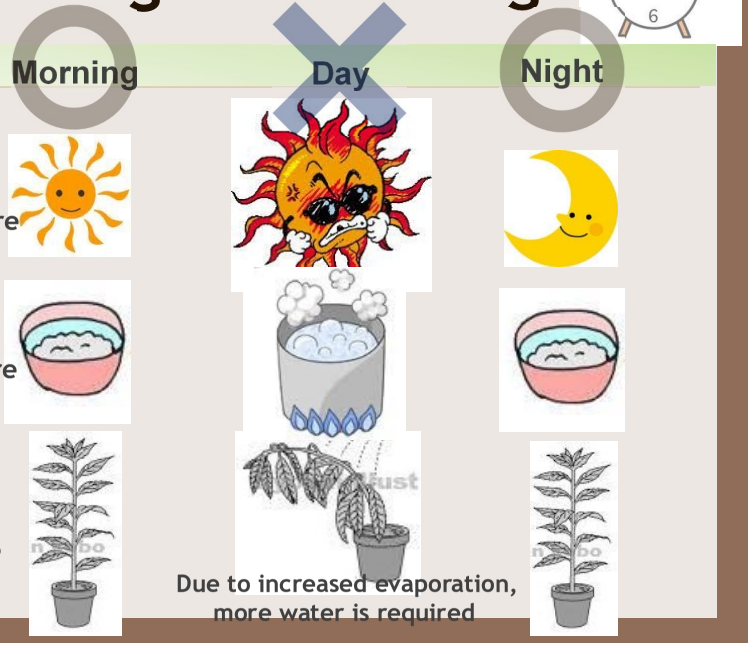
If it's too big, furrow irrigation cannot be applied, especially when plants are still at an early stage

Frequency of watering

Even when surface looks dry, soil maintains moisture just under the surface. Frequency and amount of watering should be carefully decided; too much water also harms the crops.

Timing of watering





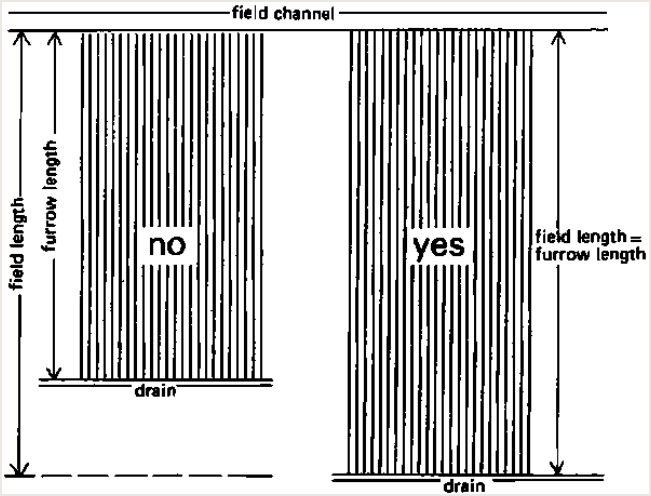
Due to increased evaporation, more water is required

Other Surface Types

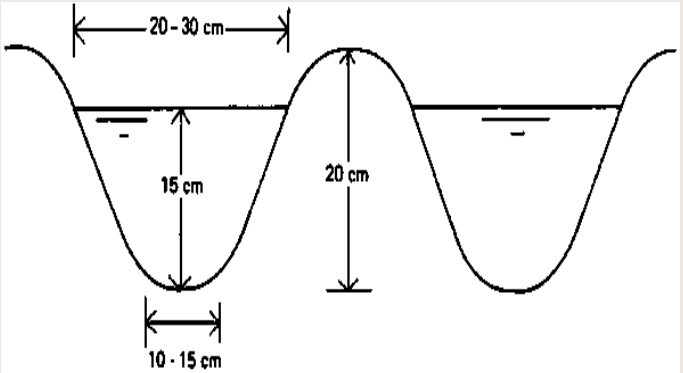
Furrow irrigation

Furrow irrigation in Irish potato

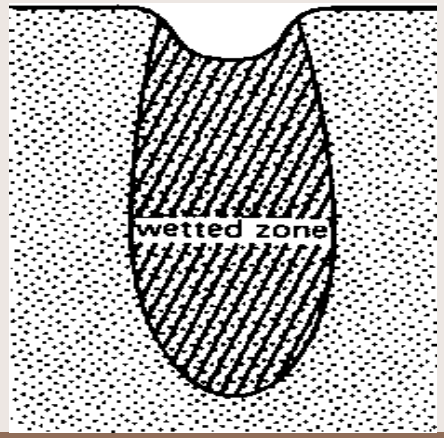
Field length = Furrow length



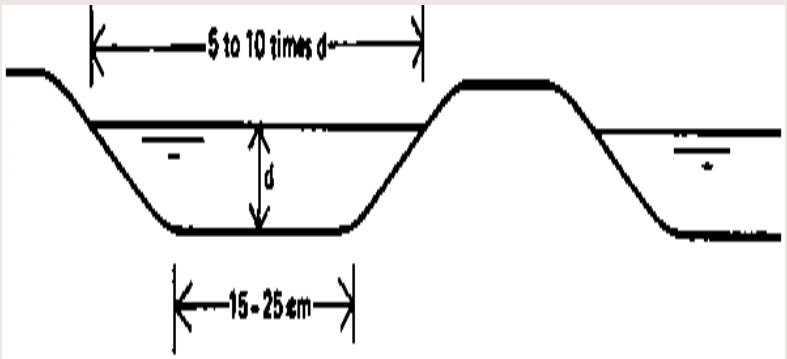
A deep, narrow furrows on a sandy soil



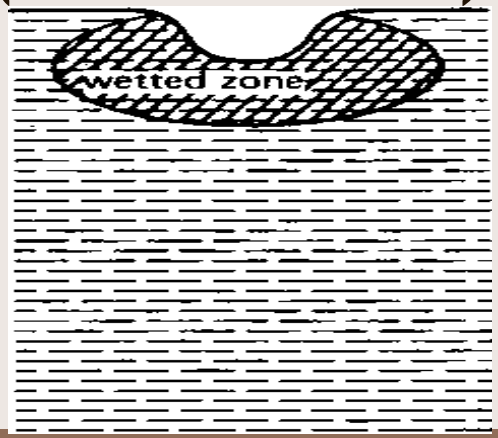
Wetting patterns in furrows, (A – SAND SOIL)



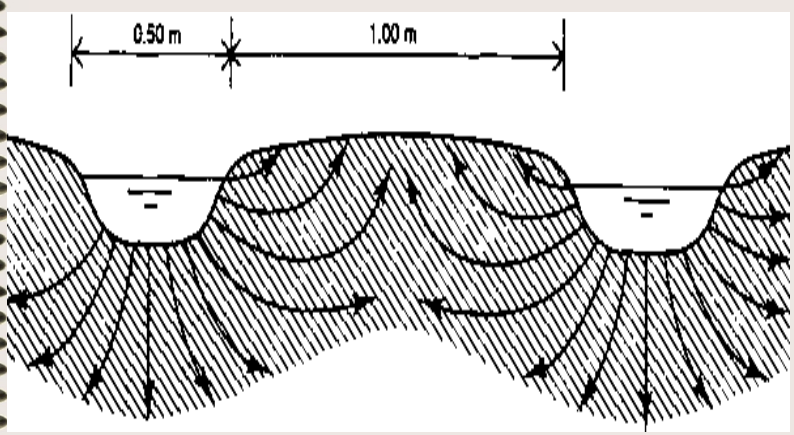
A wide, shallow furrow on a clay soil



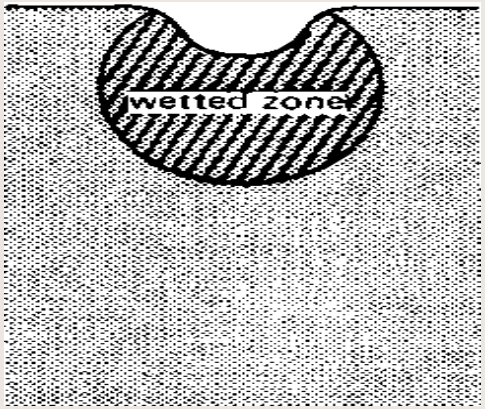
Wetting patterns in furrows, (C – CLAY SOIL)



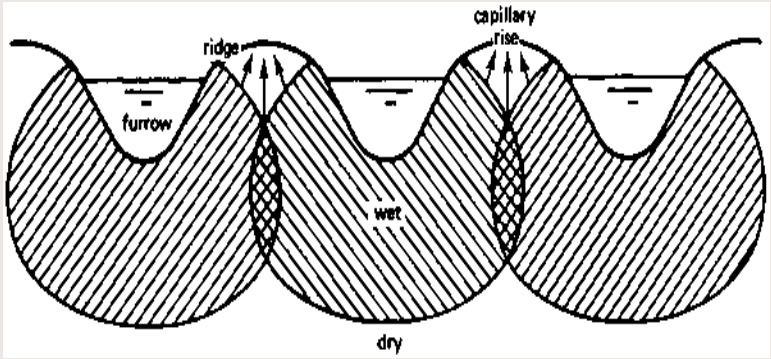
A double-ridged furrow



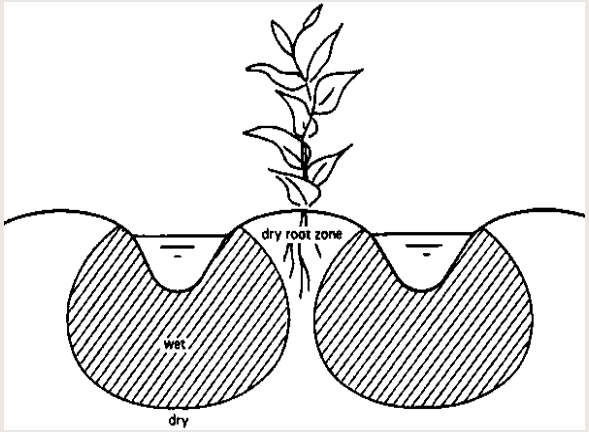
Wetting patterns in furrows, (B – LOAM SOIL)



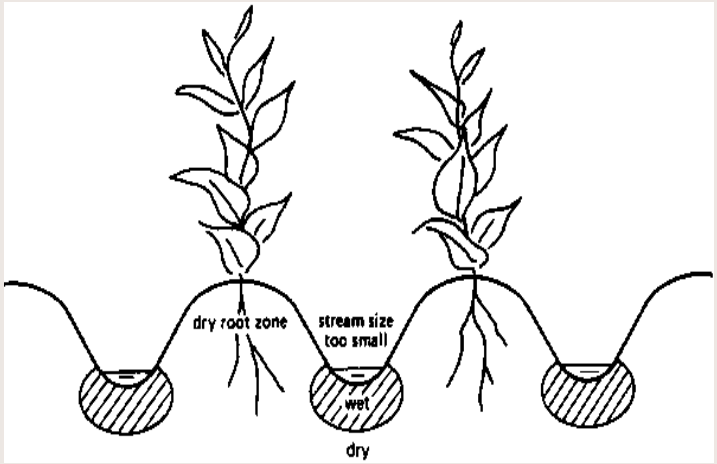
Ideal wetting pattern



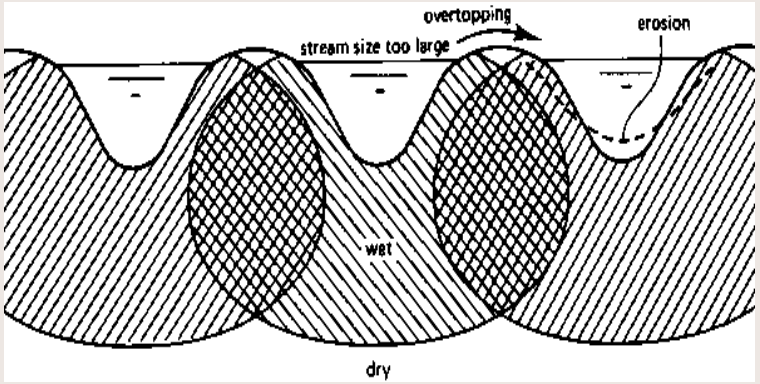
The spacing between two adjacent furrows is too wide



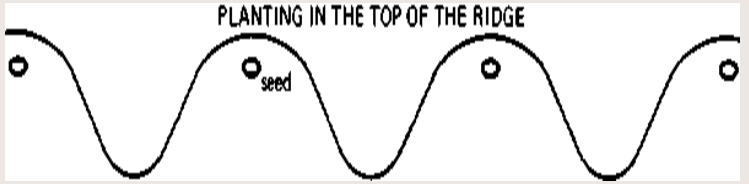
Stream size is too small to wet the ridge



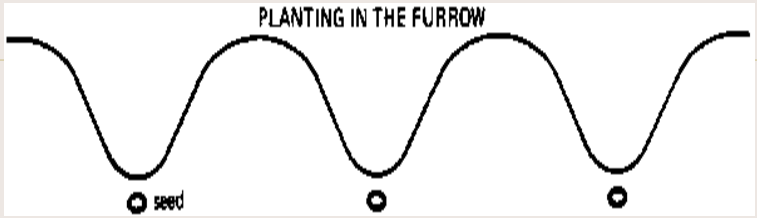
Stream size too large causing overtopping or erosion



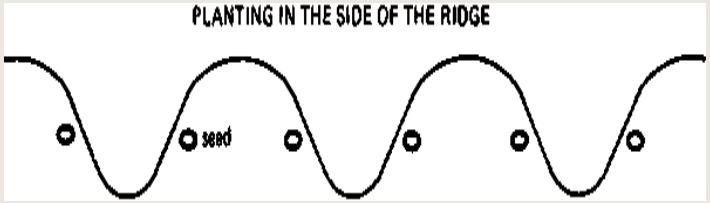
Protection against water logging



Protection against water scarcity



Protection against accumulation of salt



Maintenance of Furrows

Furrow systems should be maintained regularly;

- During irrigation it should be checked if water reaches the downstream end of all furrows.
- There should be no dry spots or places where water stays ponding.
- Overtopping of ridges should not occur. The field channels and drains should be kept free from weeds.

Furrow running down stream

Basin Irrigation

- Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields.

Basin Types

Basin Irrigation

End of Presentation
THANK YOU

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Expansion of COmmunity-Based Smallholder Irrigation Development Project

Module 6: Cultivation Technics for Horticulture Crops

Pre-Cultivation Activities



Contents

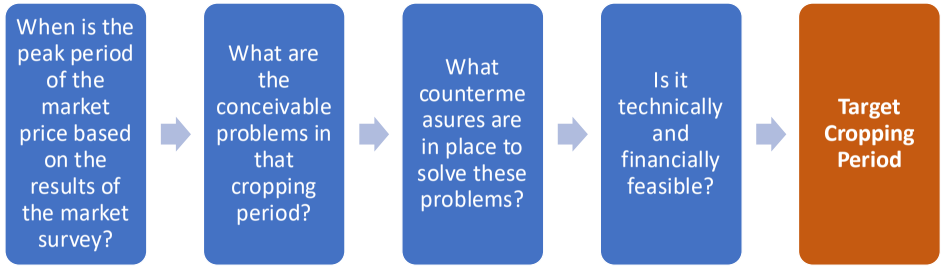
1) Making Cropping Plan
2) Crop Rotation
3) Record Keeping
4) Site Selection for a garden
5) Climatic factors affecting vegetable production
6) Cultivar Choice
7) Seed Preparation

1) Making Cropping Plan

- In making a cropping plan, it is essential to consider the results of the **market survey** before vegetable cultivation (**SHEP** Approach).
- In general, **market prices in small local markets depend on the supply of crops at a specific time**. If many farmers sell the crop at the same time, the market price will go down. Conversely, if few farmers sell the crop at the same time, the market price will go up.
- A **profitable and realistic** planting plan for the field of each target crop at a certain season is essential. In planning, the **trends of market prices and quality and cultivation environment** such as rainfall, irrigation water availability, pest, diseases, and flood should be considered.

2) Making Cropping Plan

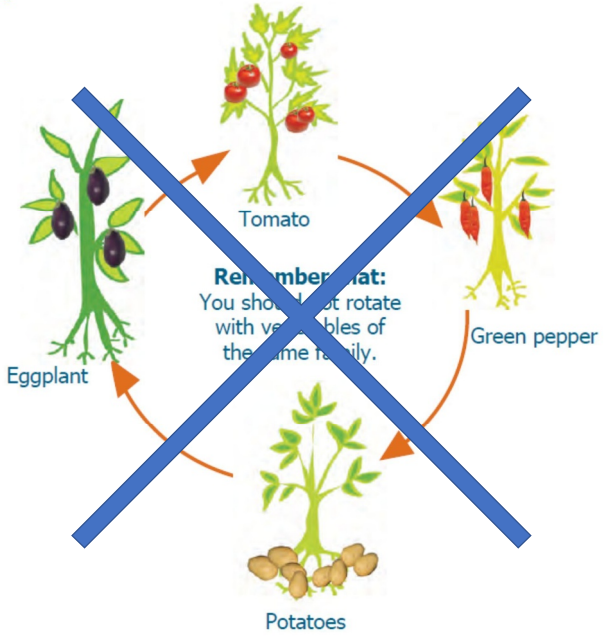
Setting-up the target cropping period



2) Crop Rotation

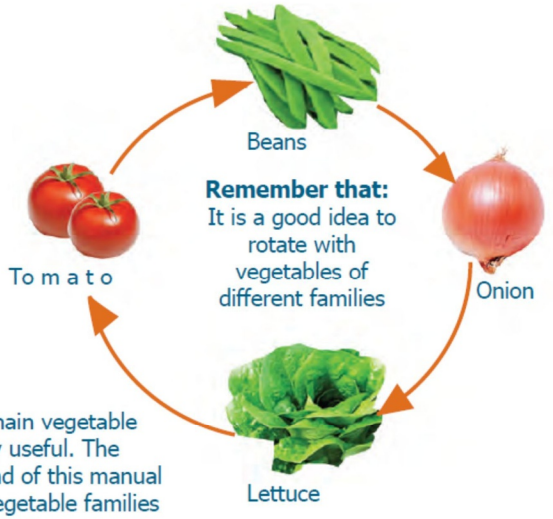
- **It is essential to set up a crop rotation schedule.** The schedule shall compose of different kinds of crops to avoid successive cultivation of crop belonging to the same family which causes replanting failure. This is attributed to soil-borne diseases and soil nutritional imbalance.
- To establish crop rotation in the field, the plant's crop family and required duration are presented in the following table to avoid successive planting of crop belonging to the same family.
- If the field is submerged with flood during the rainy season, replanting failure can be mitigated using crop rotation.

2) Crop Rotation



2) Crop Rotation

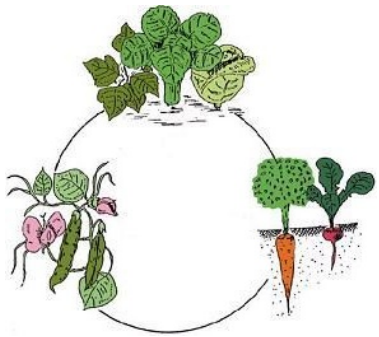
Solanaceous Family:	Tomatoes Eggplant Green pepper Potatoes
Leguminous Family:	Peas Beans
Cucurbitaceous Family:	Pumpkin Melon Watermelon



Knowing the main vegetable families is very useful. The chart at the end of this manual explains the vegetable families of all the vegetables you may wish to plant.

Crop Rotation

- It is the practice that involves changing the type of crop grown in the field *each year*, for example maize the first year, and beans the next. This is one of the pillars of CA.



Example of Crop Rotation

It is common practice to have a 2 or 3 year rotation which involves 3-4 crops.

❖Maize, soya beans, wheat rotate well together.

1. Maize- cotton
2. Maize- cotton- soybeans
3. Maize- soya beans
4. Maize- ground nuts

Other possibilities

1. Maize- cotton- sunhemp
2. Maize- cowpea
3. Pigeon pea/ crotalaria/ cowpea- cassava

2) Crop Rotation

Crop Family

Crop Family	Crops	Required Duration
Solanaceous	Tomato, Eggplant, Sweet Pepper, Hot Pepper	3-4 seasons
	Irish Potato	2-3 seasons
Cucurbits	Pumpkin	1 season
	Cucumber, Squash, Gourd, Zucchini	2-3 seasons
	Watermelon	5 seasons
Cruciferous	Cabbage, Cauliflower, Rape	2 seasons
Liliacerous	Onion, Leek, Garlic	1-2 seasons
Leguminous	French Bean, Kidney Bean, Cowpea	3-4 seasons
Umbelliferous	Carrot, Celery	1 season
Convolvulaceous	Sweet Potato	1-2 seasons

2) Crop Rotation

Example of a 3-season rotation plan for some commonly grown vegetable in Zambia

No. of Pattern	1st Season	2nd Season	3rd Season
1	Tomatoes	Cabbage	Onion
2	Cabbage	Onion	Okra
3	Rape	Beans	Onion
4	Onion	Cabbage	Okra
5	Peas	Green Maize	Rape

Crop rotation within gardens

Crop Rotation	Plot 1	Plot 2	Plot 3	Plot 4
Crop 1 March-June	Green Beans Peas	Tomatoes, Peppers	Carrots, Onions, Beetroots	Cabbage, Kale
Crop 2 July-Oct	Tomatoes, Peppers	Green beans Peas	Cabbage, Kale	Green beans Peas
Crop 3 Nov- Feb	Black sunnhemp or velvet beans	Red sunnhemp or velvet beans	Black/Red sunnhemp or velvet beans	Sunnhemp intercropped with green maize or sweet corn

Principles of crop rotation

- Crops of different plan families, e.g. brassicas or root crop should be alternated.
- Add leguminous plants to maintain soil fertility.
- Alternate high feeders and less demanding crops or leguminous.
- Crops that suppress weed such as squashes should be alternated with non weed suppressors.
- Intercropping should be carried out where possible.
- Add green manure crops.

3) Record Keeping

- Record keeping should be an integral activity for successful smallholder gardening. Record keeping is important in determining the profitability of a particular crop being grown.
- A smallholder vegetable grower would be making a loss of the produce is sold below the break-even price. Without records of variable costs, it is impossible for the producer to know whether there are losses or profits being realized.
- Record keeping helps to give an insight into the economic worthiness of the smallholder vegetable production enterprise. This information is also useful to lobby for financial support from potential creditors.

4) Site Selection for the garden

- A good site is near a reliable source of water, has **well drained fertile soils** and optimum availability of environmental crop growth factors such as **sunlight and solar** radiation. Away from high trees.
- The site should ensure minimum presence of adverse factors especially **persistent weeds, strong winds, pests, disease and marauding domestic and wild animals.**
- Because vegetable crops have a high demand for nutrients, **the soils status factor** should be given serious consideration when choosing a site. Loamy and other closely related soils offer the best results for vegetable production.

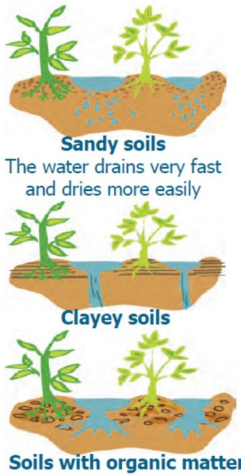
4) Site Selection for the garden

Important! One of the most essential jobs in your home garden is to add organic matter to the soil.

Why?
Organic matter:

- increases the capacity of sandy soils to retain water.
- softens heavy soils (clay), increasing aeration and improving root growth.
- serves as food for the soil organisms.

Where can organic matter for the home garden be obtained?



4) Site Selection for the garden

- Vegetable crops differ in their requirements for soil pH. Most vegetable crops grow within a pH range of 5.5 to 7.0 (moderately acid to neutral)
- Lettuce, cabbage, spinach, beans, onions, cauliflower and muskmelons are not suited to moderately acidic or strongly acidic soil.
- If the pH is low, it is advisable to apply agriculture lime to reduce the soil acidity.

4) Site Selection for the garden

Soil pH and Crop Suitability

- Above 7.5: Strongly alkaline; deficiencies of zinc, boron, iron and manganese likely on many crops.
- 7.0-7.5: Alkaline; usually because of free lime. Satisfactory for most crops although higher than desirable.
- 6.0-7.0: Neutral; Highly satisfactory for Lucerne and legumes. Satisfactory for most other crops.
- 5.5-6.0: Slightly acidic; Highly satisfactory for almost all crops. `L` mixture not required.
- 5.0-5.5: Moderately acidic; Satisfactory for most crops but 'L' mixture may be required for maintenance in special circumstances.
- 4.5-5.0: Strongly acidic; There is a progressive risk of fertility being adversely affected. Application of maintenance levels of 'L' mixture necessary.
- Below 4.5: Very strongly acid; Severe infertility likely, application of 'L' mixture essential before planting.

5) Climatic factors affecting vegetable production

- Temperature, humidity, soil radiation, light and day length are among some factors that affect the growth of specific vegetable crops in specific ways.
- In general, most exotic vegetable crops tend to **perform better in the cool dry season from April to August.**
- In Zambia, the hot dry season from September to November is associated with poor performance due to high temperatures and the high incidence of pests. The hot humid conditions prevalent in the rainy season also reduce the performance of exotic vegetables due to the higher incidence of diseases.

6) Cultivar Choice

- Though seed dealers are making many vegetable cultivars, not all of them are adaptable to Zambian agroecological conditions.
- The farmers to be aware of the specific adaptability of cultivars with respect to seasons, pests and disease in order to make the right choice at any given time.
- Research has been done by the Vegetable Research Program in Zambia to identify season specific, high yielding cultivars of some major vegetable crops.

6) Cultivar Choice cont'

- Before buying, check the product's expiration date or packed date. It is normally printed on the package. "EXP DATE" means expiration date of seed germination and "PKD" or "Packed Date" means the date of seed packing at a company.

6) Cultivar Choice

Recommendations of some vegetable cultivars specific to seasons

Crop	Name of Cultivars to grow during winter season (April – July)	Name of Cultivars to grow during summer and rainy season (August – March)
Cabbage	Any approved cabbage cultivar including open pollination ones; Copenhagen Market, Main crop, Golden Acre, Sugar-loaf, Brunswick Ladu.	Recommended to grow hybrids; Riana F1, Marcanta F1, Star 3317 F1, Cotton F1, Gloria F1, Rotan F1
Tomato	Any recommended Tomato Cultivar	Money maker, Newton, Rodade, Trinity, Roma VFN, Rossol VFN
Onion	Any recommended Onion Cultivar e.g Taxas grano	No suitable onion cultivar. Red skinned cultivars; Pusa-red, Red creole are slightly better
Rape and Tronchuda	Giant Rape, Samo, Karate, Couve, Portuguese, Villinda. Local Rape for late planting.	Local Rapes; Nanga Rape, Prior, NIRS-1, Giant Rape

Module 6: Cultivation Technics for Horticulture Crops (cont'd)

Expansion of Community-Based Smallholder Irrigation Development Project
(E-COBSI)

Horticulture Crops Cultivation

E-COBSI

Small holder Horticulture; The underfunded rural poverty reduction option in Zambia

- Zambia has recently been experiencing about 10% agricultural growth with out significant reduction in rural poverty IAPRI.
- Horticultural production can increase income by about 164% per hectare (IAPRI)
- Rain fed crop (maize) has accounted for more than 50% of agricultural budget
- 70% of smallholder farmers who produce 75% of the national staple food have not benefited (still in poverty)

Rural agricultural livelihood survey

Horticultural crops have higher gross margin profits as compared to field crops (maize).

Production calendar

The calendar below shows different types of crops and when they can be grown in the year.

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Cabbage (1)	Cabbage (1)	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage	Cabbage
Cauliflower	Cauliflower	Cauliflower	Cauliflower	Cauliflower	Cauliflower	Spinach	Spinach	Spinach	Carrot	Spinach	Carrot (1)
Carrot (1)	Carrot (1)	Chinese-Cabbage	Chinese-Cabbage	Chinese-Cabbage	Chinese-Cabbage	Carrot	Carrot	Carrot	Radish	Carrot	Radish
Radish	Radish	Beetroot	Beetroot	Beetroot	Beetroot				Tomato		Tomato (1)
Tomato (1)	Tomato (1)	Radish	Radish	Radish	Radish	Tomato (1)	Beans	Tomato	Green pepper	Tomato	Squash
Potato (1)	Potato (1)	Beans			Tomato(1)	Chinese-Cabbage		Egg plant	Squash	Radish	Potato
Okra	Okra	Egg plant	Green pepper	Green pepper	Lettuce	Beetroot	Cucumber	Cucumber	Okra	Green pepper	Okra
Lettuce	Lettuce	Potato(1)			Spinach	Radish	Squash	Squash	Lettuce	Cucumber	Lettuce
Chinese-Cabbage	Chinese-Cabbage	Okra	Lettuce	Lettuce	Carrot	Potato	Okra	muskmelon	Onion	Squash	Onion(2)
Onion(2)		Lettuce	Spinach	Spinach			Muskmelon	Okra	Beans	Lettuce	Beans
Beans	Beans	Carrot	Carrot	Carrot	Peas		Lettuce	Lettuce	Eggplant	Chinese-Cabbage	Pumpkin
Green pepper	Green pepper	Onion	Onion	Onion	Potato		Chinese-Cabbage	Chinese-Cabbage	Cucumber	Onion (1)	Green pepper
Cucumber(1)	Cucumber(1)	Peas	Peas	Peas			Beetroot	Beetroot	Potato	Beans	Cucumber
		Tomato	Egg Plant	Egg Plant			Egg plant	Radish		Egg Plant	
		Green pepper	Potato	Potato			Green Pepper			Potato	
		Cucumber(1)	Cucumber				Pumpkin	Green Pepper		Pumpkin	
							Potato	Pumpkin		Okra	
							Watermelon	Potato			
								Watermelon			

Horticultural production

- Horticultural Production is a series of activities that includes;

i. Land preparation
ii. Nursery bed preparation
iii. Transplanting
iv. Fertilizer application-basal and topdressing
v. Pest and disease protection
vi. Harvesting

Land preparation

- Good land preparation, start by clearing the land - grass, stones, stumps and trees
- Mark sites for beds.
- Cultivate the soil to **the depth of 30 cm**
- If it's an old garden, put crop residues at the bottom and dig (30 cm deep) the new beds by covering the residues.

Land preparation

- Lime (if necessary) a month before transplanting
- Manure can be applied immediately before planting if the material is sufficiently dry and decomposed.
- Don't put fresh manure
- Beds width should be between 90cm to 120cm
- Length depends on what is required and practical.

How should the soil be prepared?

1. Scatter a layer of 2 to 5 kilograms (4-10 lbs) of organic fertilizer or manure for each square meter (3ft x 3ft) of land. Mix it into the top 10 centi-meters (4 in.) of the soil.
2. Push the point of the spade 30 centimetres (1 ft) into the ground, then lift the soil and let it fall upside down.
3. Continue turning the soil in for the length of the garden and then turn back at the end of the row and do the same on the other side.

How should the soil be prepared?

4. Remove large stones and garbage.
5. When all the earth has been turned, go over it with the rake to flatten and break up any lumps.
6. If the region where you live is very rainy or very dry, the soil can be covered with mulch so that crusts do not form or it doesn´t get baked by the sun.

Types of permanent/plant bed

The following are some examples of types of beds which may be considered.

1. Raised Beds
2. Flat Beds
3. Ridges
4. Sunken Beds

Raised bed

- Widely in growing vegetables in both the rainy season and the dry season.
- Top soil is scraped in to make beds which are slightly raised.
- A small ridge is made around the edge
- suitable for use all year round.

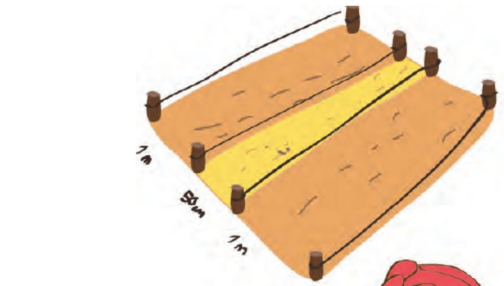
Advantages of raised bed

- Drainage is improved during the wet season as the bed is slightly raised.
- The ridge around the bed prevents nutrient loss and soil erosion.

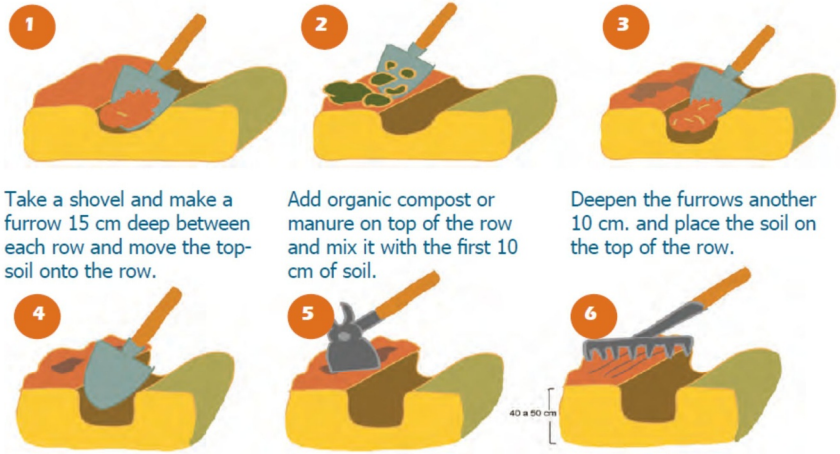
Disadvantages of raised bed

- Water loss may be greater during the dry season due to the beds being slightly raised

How to prepare raised bed?



The rows can be marked off using string tied to wooden stakes.



Flat Beds

- Beds are prepared at ground level.
- Slightly raised paths may then be prepared between the beds to give an overall basin effect.
- Suitable for vegetables being grown and flooding irrigation is to be used.
- Helps to conserve water.

Advantages of flat bed

- Water loss is reduced during the dry season
- Watering can be carried by simply flooding the basins
- Fertilizer and manure are not easily washed away
- Requires less labor

Disadvantages of flat bed

- During the rainy season soil may become waterlogged if the soil is not well drained
- There is no increased depth of topsoil available for plant roots.
- Weeding becomes more difficult.

Ridges

- Small ridges are prepared approximately 90 cm apart and vegetables are planted along the ridges either in single rows or double rows.
- Often used for larger scale vegetable production.

Advantage

- It allows for easy of watering by furrow irrigation.

Disadvantage

- Note on location of the ridges and the land slope.
- Slopes of greater than 2% will lead to soil erosion while slopes which are fat will not allow the water to run along the furrows.

Sunken beds

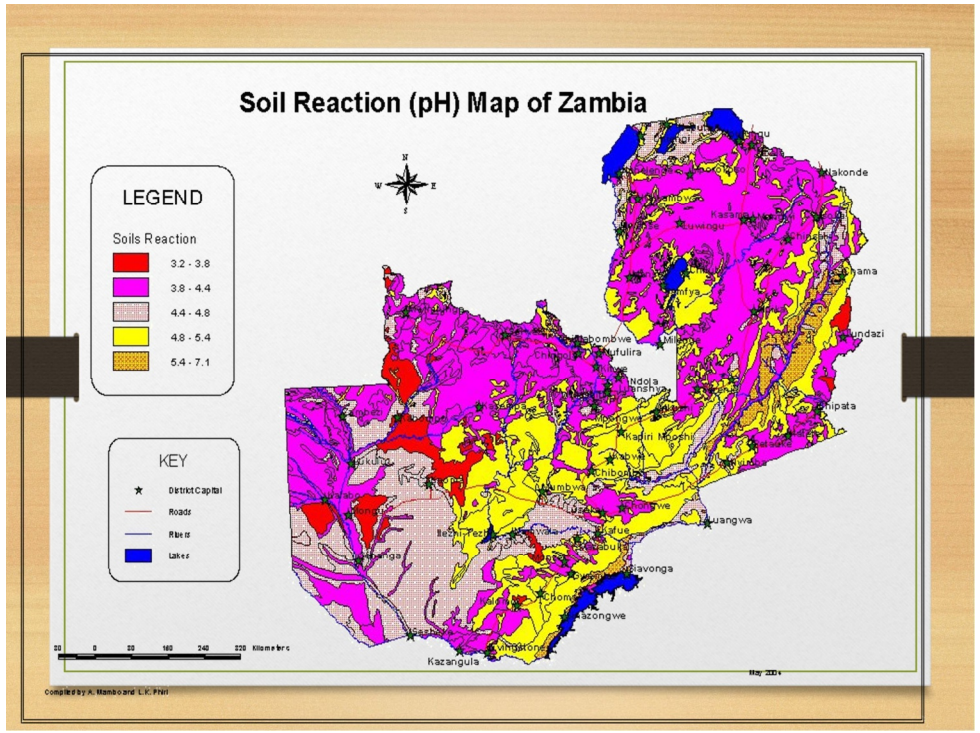
- is applied to a very flat areas, and not to steep topography.
- Sunken beds are 10 - 15 cm deep & recommended for well drained soils only.
- Almost all the crops are grown in sunken beds during dry season, but others prefer flat beds for cabbage & watermelon

Advantage

- We recommend sunken beds or beds with basins is during dry season when water is the limiting factor.
- Sunken beds help to store water even better when they mulch them.
- The amount of water can be given with a minimum amount of labor if beds are well leveled
- Water losses can be kept low by minimum run-off, and
- Beds last for a long time once they are constructed.

Disadvantage

- in some areas where the soils are clay or the water level is high e.g dambos areas, we usually recommend raised beds.
- Many vegetables are vulnerable to excess water condition leading diseases. So sunken beds are not suitable to clay soil with poor drainage



Soil Acidity

- In Zambia approximately 40 % affected
- A large part of the project area is categorized as acid soil (pH 4.4 or less)
- Severe root pruning limits root access to water in the subsoil
- Application of lime is a quick measure (ash also has similar effect)
- Selection of crops that are relatively tolerant to acid soil (Irish potato, S-potato, watermelon, maize, pumpkin, eggplant, and tomato)

Horticultural Nursery

Factors to be considered for raising a nursery

- Land close to the house
- Well exposed to the sun, but protected against severe heat
- Well protected against animal damage and strong winds

Nursery Establishment

- Select site for the ground nursery on virgin land or one that has been rested.
- The size of the seed bed depends on the amount of seed to be sown, which ultimately depends on the field area to be planted.
- Sterilize the soil-fire or plastic.

Nursery Establishment cont'

- Dig over several times attain a fine tilth, crush the bigger lumps and remove any large particles
- Livestock manure or compost should be added to the seed bed (Add 5kg/10m^2)
- Add compound fertiliser such as 'D' 100g/m^2(approximately two adult handfuls).
- Soil in the bed should be irrigated to field capacity

Raised Nursery Bed

Fig. No. 3.2.1.1: Raised bed

Source: JICA Project Team

Sunken Nursery Bed

Fig. No.3.2.3.1: Sunken nursery bed (For hot & dry season bed)

Source: JICA Project Team

After Nursery Establishment cont'

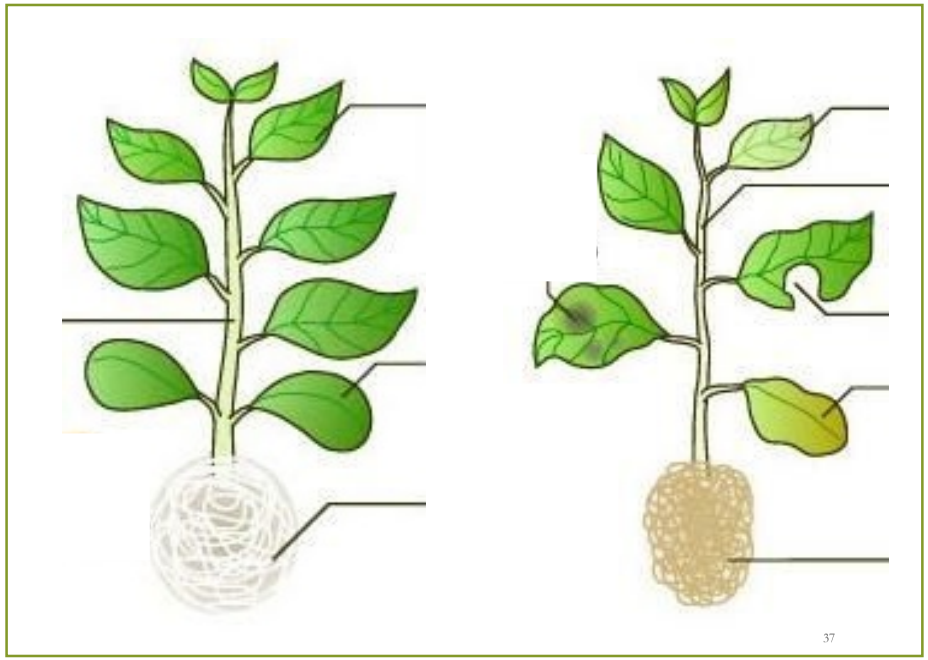
- Check the seedbed twice a day.
- Remove the paper and dried grass as soon as the first seed germinates.
- Water daily with water and nutrient solution.
- Loosen the soil twice a week to avoid the formation of hard layers and the development of algae.
- Earth up (mold) or put the substrate around the bottom of the plants to strengthen the development of the roots.

After Nursery Establishment cont'

- You should have a separate seedbed for each species. Don´t mix the seeds of different vegetables.
- Water the plants carefully, so that the seedlings are not damaged.
- The weeds need to be removed because they compete with the seedlings for nutrients and water.
- You can protect the seedlings by placing glass or transparent plastic over the containers, taking care that they are not in direct sunlight.

Nursery Management

- Sowing
- Weeding and Watering
- Mulching
- Disease and pest
- Shading



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Transplanting

- Transplanting –transfer of seedlings from the nursery to permanent bed or plant bed.
- Depending of the type of seedling and management, can be transplanted **4-5 weeks later after sowing**.
- Before transplanting, **hardening** should be done.
- Prepare a weed free plant bed. Loosen and aerate the plant bed by tilling
- **Water seedlings in before transplanting-prevent root shock**
- Should be **done early in the morning or cloudy day**

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Transplanting

- Prepare a hole large enough for seedlings.
- Carefully remove seedlings from its nursery bed, tray . Try not to disturb the roots.
- Feed seedlings to kick start growth. Apply compost or decomposed manure.
- **Water seedlings thoroughly immediately after transplanting**
- Water seedlings to maintain soil moisture and regulate temperature.

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Tips-transplanting

- Prepare your soil ahead of time making sure its moist before transplanting.
- Be sure all of the roots are covered with the soil.
- Gently press the soil around the base of your planting, roots needs contact with soil.

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Fertiliser Application-Permanent bed

- In Zambia, 800kg/ha of 'D' Compound with sulphur due to its role in enhancing bulb keeping quality (shelf life) and pungency.
- Apply top dressing after 4 weeks after transplanting . Apply ammonium nitrate at the rate of 200kg/ha or Urea at 150kg/ha during top dressing. In case of boron deficiency, apply borate at 5kg/ha
- Ensure that each plant gets appropriate dose of fertiliser.

Pest and disease protection

Vegetable growing

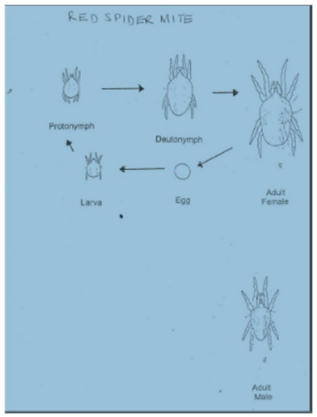
Introduction

- Plant protection against -insect pest, mites, nematodes, weeds and diseases,
- Plant pest –any living organism or infectious substance that can injure, infect or damage plants or plants products; including insects, mites, nematodes, bacteria and fungi

Insect pest

A living organism with 3 segmented parts of the body and has three pairs of legs:

- Chewing- armyworms, termites, grasshoppers, leaf hopers, beetles and locust
- Piercing and Sucking- inject toxic materials and some transmit aphids, leaf footed bugs, white flies, mealy bugs
- Internal Feeding – They feed on internal tissues of leaves and fruit-usually at larvae stage, leaf miner,
- Subterranean Insects- attack the plants from the root.



Mites

- Mites are small living organisms belonging to the class Arachnida and subclass Acari.
- Red spider mites - host plants includes; carrots, egg plant, sweet potatoes,
- Control of Mites; Chemical: Miticides - Abamectic
- Cultural:, weed control, crop rotation, mixed cropping minimizing in dust trap or boarder crops

Nematodes

- The free living and plant parasitic nematodes are generally microscopic ranging from 0.3mm – 1 mm in length.
- Plants affected includes cucumber, tomato, okra, carrots pepper and eggplant.
- Signs of Nematodes Infestation ; unthrifty, galled and decayed roots, stunted, yellowish

Control of Nematodes

- **Rotating crops**-susceptible crops should be followed by less susceptible crop
- Chemical –

1. Carbamates: Furadan -Carbofuran AI ,Temik – Aldicab AI ,Lane Cleothocarb AI
2. Organophosphate -Phorate

Vegetable Diseases

- Strong healthy vegetable plants can fight off many infections. But stressed plants are susceptible to damage from diseases.

- Some vegetable plant diseases cause the seed to decay or seedlings to die before emergence.

- Other attach plant roots, stems, and fruits causing leaf spots, wilts, cankers or fruits rots. Vegetable diseases can be carried on the seed or in the soil or spread by insects

Two types of diseases

- Non-infectious the disorder is a direct result of a deficient or excessive supply of an essential growth factor, such as light, oxygen, soil moisture and heat.
- Infectious diseases –caused by parasites; bacteria, fungi and virus can range from mild leaf to severity.
- Symptoms of the diseases; Damping off, Wilt, Spot Blight, Mildew, Galls, Leaf curl

Fungal diseases in vegetables

- Fungi reproduce by means of spores which are specialised propagated or reproductive bodies which are formed asexually or sexually.
- Example; Early Blight, Late Blight, Powderly Mildew, Anthracnose
- Control of fungal diseases; plant health seedlings, avoid aerial watering, water early in the day, don't over crowd plants, use preventive and curative fungicides

Bacterial vegetable diseases

- Bacteria are an extremely small, microscopic, unicellular micro-organisms that reproduce by fission- Black rot - Brassica and bacteria canker-Tomato &Chilli
- Pathogens enter through wounds or natural openings, wounds-insect bite or tools
- Found in the soil, crop debris and seeds
- Wet and warm favours the development

Control of bacterial disease

- Resistant varieties
- Use clean seedlings
- Crop rotation
- Weeding and remove crop debris, that can host plants
- Isolate and destroy affected plants

Virus vegetable diseases

- Viruses are sub microscopic organisms, multiply only inside living cells and have ability to cause disease.
- Caused by vectors- aphids ,thrips and white flies which sucking the plant sap.
- Vegetable diseases includes; **mosaic virus**

Symptoms;

- local necrotic lesions, chlorosis, yellowing, greening, stunting,

Control viral disease in vegetables

- Vegetable virus can not be cured but prevented
- **Crop rotation**-avoid the availability of same host
- Credible source of propagation materials
- Destroy diseased plants
- **Management of pest vectors-piecing insects**
- Understanding non crop host e.g. Cucumber mosaic virus- milk weeds

Preventive pests and diseases control before chemical applies

- Choose vegetables and varieties that are more resistant: some pests and diseases do not cause too much damage to some vegetables.
- Crop rotation
- Weeding, sanitation of garden (e.g. remove crop debris)
- Proper soil (e.g. use of FYM, soil PH) and water management
- Companion plants, inter cropping
- Minimize mechanical damage to crops and damage by insect pests
- Proper spacing of crops (good ventilation)
- Mulching
- Shelter for Tomato production during rainy season
- Soil solarization

Pest and diseases control methods after prevalence of them

- If the plants are already infected, isolate and destroy them and prune infected leaves, but avoid excessive handling of diseased plants; if the disease is systemic and has spread throughout the plant, the plant cannot recover and should be destroyed (burning or burying)
- Hand picking of insects
- Apply chemicals

Protection Equipment of Agrochemicals

	Gloves		Eye protection
	Gum-boot		Hats
	Masks		

Protection Equipment of Agrochemicals

For your safety, put on a hat or cap and worn a cloth or towel to cover nose and mouth!!

Use a mask to prevent inhale of fungicide. If a mask is not available, roll a towel around face to cover nose and mouth.

Post harvest in vegetables

Harvesting

- Maintain quality of the vegetables.
- Good quality is first step towards successful post-harvest handling and marketing.
- Vegetables should be harvested within the desired form, following pre-set quality parameters.
- Quality parameters are arrived at based on what the consumer requires in a product.
- Avoid bruising or other damage to both the produce and the mother plant.
- Soil moisture is required for pre harvesting
- Depending on the market vegetables may be harvested mature or immature e.g. green maize, shelling peas and cooking carrots.

Post harvesting

- Onions, garlic and pumpkins are easy to store, but they need some special attention. Nevertheless, most vegetables spoil quickly. You need to keep them in a cool place and only for a short period only.
- Eliminate vegetables that are soft, damaged, and sick or infected with pests, as they will affect the healthy vegetables.
- When you cut the leaves on root vegetables like carrots, beets and radishes, trim tops to 1 cm.
- Every vegetable is stored differently, according to its characteristics

Post harvesting

- You can store vegetables in any room, which is neither too cool, nor too hot. Also, vegetables always should be stored in a shady place.
- Some fruits, such as tomatoes and melons, can be harvested before reaching maturity and kept until they can be eaten. Others, like onions and garlic, must be cured/dried after harvested or harvested when they are dry, and kept in bags or nets.
- Most vegetables need to be stored in a very cool place (10-15 °C).
- In the coolest room in the house. The basement is the best place.
- There always should be room for air to circulate.
- You can use paper or cloth bags to protect the vegetables. Do not store in black plastic bags.

Summary

- Importance of horticulture to rural community
- Land preparation
- Nursery establishment
- Pest and diseases
- Harvesting

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Module 6: Cultivation Technics for Horticulture Crops (cont'd)

Appropriate Farming Technologies

Crop Protection minimizing use of Agro-chemicals (Prevention of pests and diseases control)

Crop Protection (Prevention of pests and diseases control)

- If farmers minimize the use of agro-chemicals, they can produce healthy, nutritious food of sufficient quantity whilst minimizing harm to the environment and maximizing the benefit.
- Farmers can introduce following control methods without any budget.
  1) Crop rotation (please refer to Module 3.02)
  2) Companion crops
  3) Intercropping
  4) Organic pesticides

2) Companion Cropping

A Cultural Approach
for Better Vegetable Production

Companion planting

- Companion planting is simply a form of poly culture
- Companion planting is the planting of different plants in close proximity that will provide different benefits for each other. It is beneficial relationship between different plants.

Benefits of Companion Planting;

- **Pest Repellent:** certain plants give off chemicals either from their leaves, flowers or roots which will repel or supress pests, protecting its neighbours.

  E.g. marigolds deter nematodes

Companion planting

Benefits of Companion Planting;

- **Nitrogen Fixers:** Beans, clover, peas and some other plants have nodules on the roots which grow Rhizobium bacteria. These helpful bacteria take nitrogen from the atmosphere and fix it into the soil in a form that can be used plants. This nitrogen fixing also benefits neighbouring plants as well as later crop planted in the same location.
- **Sacrificial Planting (Banker crops):** If you have a plant that is particularly susceptive to a pest, you plant another plant nearby that the pests prefer as a decoy (pulling approach). The pests flock to that plants, rather than your vegetable. You will still get some pests on your vegetable, not as many. Most of pests will be on the sacrificial plant and can them be easily disposed of. Apply more amount of fertilizer for the "decoy" plant as it attracts insects more

Companion planting

Benefits of Companion Planting;

- **Enhancing flavour:** Some pairings will improve the flavour of vegetables. e.g. Basil makes tomatoes more flavoursome.
- **Camouflage:** A lot of pests use smell to find crops or they look for the shape of plant. By choosing companion plants with as strong smell. you can confuse many pests. For those pests that hunt by sight, companion plants can confuse the shape of the plant too (pushing approach).

Companion planting

Benefits of Companion Planting;

- **Shading:** Known as stacking in permaculture or as level interactions, this is the principle of planting taller plants so that they provide shelter and shade for more delicate plants. e.g. three sisters
- **Attracting beneficial insects:** Farm needs pollinators as well as pest predators such as hoverflies, lacewings, spiders, parasitic wasps, predatory mites, and ladybirds. Planting the right companion plants will attract insects which will keep the problem pests down and pollinate your vegetable plants.

Companion planting

Benefits of Companion Planting;

- **Increasing biodiversity:** A good mix of plants creates a much more resilient ecosystem including soil condition. Pests, adverse weather conditions, diseases will not wipe out your entire crop, but instead just damage a portion of it, and even that can be minimized with the right planting.
- Maximizing space efficiency: Combine taller crop and shorter crop that can grow under shed (ex. maize and soybean)

Proper use of companion planting increase a yield of vegetables while decreasing works. It does not take up extra space and does not detract from maincrops. It means vegetables are healthier, grow better and taste much nicer.

Summary: Advantages of Companion Cropping

1. Avoiding pests and diseases
2. Accelerating growth of crops
3. Improving farming environment

Note: effect of companion cropping is not as immediate and strong as compared to agri.-chemicals

Example of Companion planting

Trap cropping

- A **trap crop** is a plant that attracts agricultural pests, usually insects, away from nearby crops. This can save the main crop from decimation by pests without the use of pesticides.
- Trap crops can be planted around the circumference of the field to be protected, or interspersed among them, for example being planted every ninth row.

Example of Companion planting

Sequence Cropping

- This involves growing two crops in the same field one after the other in the *same year* e.g. maize in the long rains then beans during the short rains . It is done by either planting two major crops or one major crop followed by a cover crop growing alternating.

Example of Companion planting

Strip cropping

The system involves planting broad strips of several crops (a strip can be 3-9m wide). Strips can be rotated .

The system has the following advantages:

- Crop diversification, improved soil fertility, reduced soil erosion, reduction of weeds, pests and diseases and residues from one strip may be used as inputs in another.
- Crop management is easy and competition between crops is reduced

Example of Companion planting

Relay Cropping

This is the growing of one crop and planting another *before harvesting the first*
e.g. growing maize then sowing beans between rows four weeks later.

Advantages

•No competition between main crop and intercrop

•Allows the use of the field for comparatively longer time.

Recommended Combination

Ex. Cabbage and lettuce

- Cabbage warm attacks only *brassica* family (cabbage) but not *compositae* (lettuce)
- In addition, cabbage warm doesn't like the smell of lettuce

Note: effect may vary depending on the environmental condition of the farm

Recommended Combination

Ex. Maize and Soybean

- Corn borer, a pest of maize and stink bug, a pest of soybean inhibit to each other
- Soybean is tolerant to shade made by tall maize plants
- Soybean provides maize with a positive effect of nitrogen fixation

Note: effect may vary depending on the environmental condition of the farm

Recommended Combination

Ex. Basil and Rape/Cabbage

- Basil suppresses striped flea beetle, a common pest of brassica family like rape.
- Basil also discourages aphid and spider mite
- However, it doesn't work against cutwarm, cabbage warm, and diamondback moth

Note: effect may vary depending on the environmental condition of the farm

Recommended Combination

Ex. Tomato and Groundnut

- Tomato is susceptible to excessive moisture; G-nuts stabilizes the soil moisture
- Rizosphere, or root area, of both crops are different, avoiding excessive competition
- G-nut acts as a banker plant, maintaining ladybeetle, a natural enemy against aphid
- G-nut improves soil fertility

Note: effect may vary depending on the environmental condition of the farm

Recommended Combination

Ex. Sweet Potato and Soybean

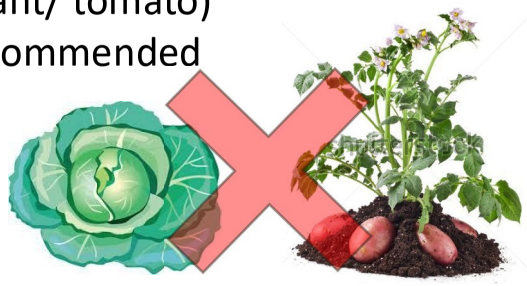
- While S-potato is growing, soybean can utilize the space—productivity increases
- S-potato acts as cover crop, keeping soil moisture against strong sunshine
- Both crops improve soil fertility with different mechanisms

Note: effect may vary depending on the environmental condition of the farm

Combination NOT Recommended

Ex. Cabbage and Potato

- Chemicals derived from both plants suppresses the growth to each other
- Combination of *Brassica* (cabbage/rape) and *Solanaceae* (eggplant/ tomato) is generally not recommended



Note: effect may vary depending on the environmental condition of the farm

General Combinations

Family	Crop	Okra	**Cabbage**	**Rape**	**Maize**	Pumpkin	Watermelon	Lettuce	Basil	Ginger	Carrot	**Irish Potato**	Chili Pepper	**Tomato**	**Eggplant**	Paprika	Strawberry	Sweet Potato	Soybean	Pea	Groundnuts	Onion	Garlic	Green Onion
Malvaceae	Okra													○						○				
Brassicaceae	**Cabbage**						◎	○		○	×													
	Rape						◎	○		○	×													
Poaceae	**Maize**												×	×				◎						
Cucurbitaceae	Pumpkin																				○	○	◎	
	Watermelon																				○	○	◎	
Compositae	Lettuce		◎	◎																				
Lamiaceae	Basil		○	○									◎	○	○									
Zingiberaceae	Ginger																							
Apiaceae	Carrot		○	○														◎						
Solanaceae	**Irish Potato**		×	×									×	×	×									
	Chili Pepper														×									
	Tomato				×			◎			×									◎				
	Eggplant	○			×			○			×									◎				
	Paprika							○			×	×								◎				
Rosaceae	Strawberry																					○	○	
Convolvulaceae	**Sweet Potato**																	◎	◎					
Leguminosae	Soybean				◎					◎							◎							
	Pea	○															◎							
	Groundnuts												◎	◎	◎									
Liliaceae/Allium	**Onion**					○	○																	
	Garlic					○	○									○								
	Green Onion					◎	◎									○								

◎ Particularly Favorable ○ Appropriate × Needs to be avoided

3) Intercropping

- Intercropping is also one mean of companion plants
- Practice of growing two or more crops with different characteristics and requirements at the same time on the same piece of land. e.g. growing alternating rows of maize and beans or cover crops in between the cereal rows.
- Reduces the occurrence of insects pest, diseases and weeds.
- By combining crops that have different patterns, the availability of water, air, and nutrients, can be better utilised
- When seed of both crops is broadcasted or dibbled without any row arrangement, the method is referred to as **mixed intercropping**.
  In this method weeding, fertilization and harvesting are difficult.
- When the main crop and the intercrop are planted in rows, the system is called row cropping. In this method, weeding and harvesting is easy, however, potential yields of both may reduce

3) Intercropping

- Advantages of intercropping:

1) an intercrop may use resources of light, water, and nutrients more efficiently than single crops planted in separate areas, and this can improve yields and income.

2) crop mixtures frequently have lower pest densities, especially of insect pests. This occurs both because the mixture confuses the insects and, if the mixture is chosen carefully, because the mixture attracts beneficial predators.

3) Intercropping may allow more effective management of cover crops.

3) Intercropping

- Disadvantages of intercropping:

  Intercropping also poses a special problem for crop rotation. One fundamental principle of crop rotation is the separation of plant families in time. This is critical for management of diseases and, to a lesser extent, insects.

  If plants from two families are mixed in the same bed or field, however, achieving a substantial time lag before replanting either of those families may be difficult. intercropping requires extra care and effort in planning and maintaining a viable crop rotation.

- A new intercropping idea should be tested first on a relatively small area. This will allow evaluation of whether it fits into the overall management system and whether benefits outweigh extra costs, labor, or yield reduction. Note that some consequences of intercropping—such as better or worse weed control, or difficulties in timing planting or harvest—may not show up in a single test year.

Example of Intercropping

Relay Cropping <Winter Maize and Climbing Bean>

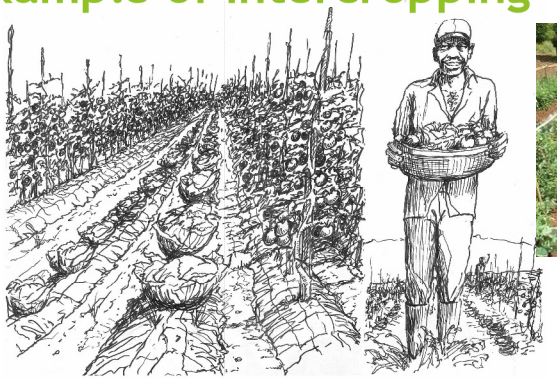
Maize is sown in row at 75cm between rows and 20cm between each plant in a row. At least 4 weeks later after sowing maize, but before the harvest, plant climbing bean so that the bean can use maize stalks as stakes. Climbing beans can produce 3-4 times more yield than bush beans.

Example of Intercropping

Two-by-Two System <Winter Maize and Soy Bean>

Instead of establishing the rows of maize with 90cm of uniform intervals, establish two rows close (50cm) and create wider gap (100cm or more) with next two rows. And in the wide gap, plant legume crops in two rows. This is why it is called 2 by 2 system. Common bean, Soybean, green gram, and groundnuts can be used in this system. By creating a wide space, legume crops can receive more sunlight and thus a total production can be increased.

Example of Intercropping



Intercropping <Cabbage-Tomato>

Tomato acts as a physical barrier against insects like Diamondback moth and it also has a characteristic to reduce the population of insect with its repellent odor. Tomato is first transplanted. Two weeks later, cabbage is planted in alternate rows.

Example of Intercropping

Intercropping <Cabbage-Onion>

Onion is famous with its repellant effect against common insects including aphids. Therefore, onion is a useful intercrop for many crops. One of recommended combination is with cabbage and carrot. However, combination with pea is not recommended.

References

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Module 6: Cultivation Technics for Horticulture Crops (cont'd)

Soil Management on Horticulture

The soil is a living thing that can also die if we don't take care of it.

Contents

1) Why we need soil management on Horticulture?
2) Soil Types and Good Soil for vegetable production
3) Tilling the soil
4) Soil improvement (Adding organic matter to the soil)
5) Compost Making
6) Green Manure
7) Control Soil Acidity
8) Fertilization (use of inorganic fertilizer)

1) Why we need soil management?

- The soil is a storehouse for all the elements plants need to grow: nutrients, organic matter, air, and water. Soil also provides support for plant roots. When properly prepared and cared for, soil can be improved each year and will continue to grow plants forever. Uncared for soil will soon become suited only for growing weeds.
- To be able to grow, develop, and produce at their best, plants must have specific elements or compounds called plant essential nutrients. A plant that lacks an essential nutrient cannot complete its life cycle—the seed may not germinate; the plant may not be able to develop roots, stems, leaves, or flowers properly; or it may not be able to produce seeds to create new plants. Often the plant itself will die.
- However, having too much of a nutrient can harm and even kill plants. For example, having too much nitrogen can cause a plant to grow more leaves but less or no fruit. Too much manganese can make the leaves turn yellow and eventually die. And excess boron can kill a plant.

1) Why we need soil management?

- You can save money and effort—and even your plants— if you know what and how much to give your plants. The plants will be healthier and more productive if you give them what they need—no more and no less.
- Fertilization is that providing necessary nutrients (organic and inorganic sources) to vegetable to the soil, before or while growing the vegetables
- Since all the necessary nutrients for vegetable growth cannot provided solely from the soil itself, we need apply fertilizer (fertilization)
- Soil Improvement; Soil problems can range from poor texture, such as heavy clay, to issues involving soil that is deficient in nutrients, waterlogged, shallow, hard packed, or just not producing the healthy crops that the gardener desires. It is possible to grow vegetables in poor soil by using artificial fertilizers but the quality of the soil will be further eroded until, finally, you won't be able to grow anything at all. That is why soil improvements is necessary can be made in some ways such as adding organic matter
- Thus fertilization and soil improvement is necessary for soil management on horticulture crops

2) Soil Types and Good Soil for vegetable production

- Zambian gardeners must work with many different soils. Some are very sandy, some are sticky clay, and others are rocky and shallow.
- Sandy soils do not hold enough water; in windy areas, blowing sand can injure vegetables. Clay soils hold too much water and do not allow enough air to enter the soil.
- Vegetables need a deep and well drained soil with adequate organic matter. Good garden soil with proper moisture will not form a hard ball when squeezed in the hand. It should crumble easily when forced between the fingers. It should not crack or crust over when dry (Fig. 1).

Figure 1. Good garden soil will crumble easily.

3) Tilling the soil

- The soil should be tilled as deeply as possible, at least 20 to 25cm. Deep tilling loosens soil and lets vegetable roots go deeper. Turn each shovelful of soil completely over (Fig. 2).
- Till soil when it is moist but not wet. Working soil when it is too wet can cause it to become rough. Spade the soil in the winter to prepare for spring planting. Winter temperatures and moisture help mellow soil. This is especially important if the soil is being worked for the first time.
- Add organic matter each year during soil preparation to build and maintain the soil. Be sure all plant material is turned under the soil. If organic material is added before planting a fall garden, it should be well-rotted, such as compost.
- Before planting, rake the soil clean and level it. Remove all sticks, rocks and other material.

Figure 2. Turn over the soil to a depth of 20 to 25cm, using a spade or rototiller.

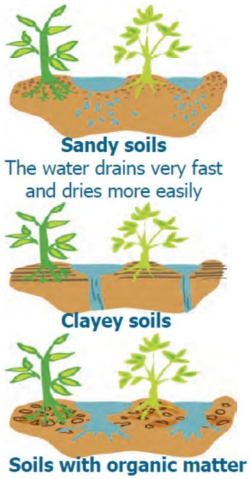
4) Soil improvement (Adding organic matter to the soil)

Important! One of the most essential jobs in your home garden is to add organic matter to the soil.

Why?
Organic matter:

- increases the capacity of sandy soils to retain water.
- softens heavy soils (clay), increasing aeration and improving root growth.
- serves as food for the soil organisms.

Where can organic matter for the home garden be obtained?



4) Soil improvement (Adding organic matter to the soil)

- Soils should be improved by adding organic matter to make soil more workable. Organic matter:
  - Loosens tight clay
  - Helps sand hold more water
  - Makes soil easier to dig
  - Adds nutrients
- Some common organic matter additives are:
  - **Plant materials:** This includes leaves, straw, and grass clippings. Work material into the soil several months before planting to allow it time to decompose. Most gardeners do this during the winter.
  - **Manure:** Use composted manure and incorporate it into the soil well ahead of planting. Do not use fresh manure, as it can damage plants and introduce diseases. Apply 30 to 40 pounds of composted manure for every 100 square feet.
  - **Compost:** Compost consists of decayed plant materials. Work it into the soil before planting.
  - **Green manure:** Green manure, also called a cover crop, is a great way to add nutrients to the soil. Green manure involves planting a crop that is meant to be incorporated into the soil to increase its fertility.
  - **Bokashi:** There is a unique method of compost called BOKASHI developed in Japan. BOKASHI compost fully utilizes the ability of aerobic microorganisms by which decomposition process can be much faster than conventional method (Learn later).

Choices of Various Methods to Add Organic Matter

Bokashi Compost

Mix the materials repeatedly (2-3 weeks)

Choices of Various Methods to Add Organic Matter

Pit Compost

Put materials in a pit (3-4 months)

Choices of Various Methods to Add Organic Matter

Windrow Compost

Cover heap with plastic sheet (2 months)

Choices of Various Methods to Add Organic Matter

Liquid Manure

Soak manure in water (1 month)

Choices of Various Methods

Methods	Time Required	Labor	Remarks
Pit Compost	3-4 months	Mid-Intensive	Easier but need more time
Windrow Compost	2 months	Mid-Intensive	Require plastic sheet
Liquid Manure	1 month	Less-Intensive	Require buckets/ short effect
Bokashi Compost	2-3 weeks	Intensive	Labor intensive but quick to be ready for dry season Ag.

5) Compost Making

Manure vs. Humus (Plant) Compost

- **Humus (Plant):**
  - **Humus compost, made up of decomposed plant material, improves soil structure by clumping soil particles to create quality tilth. The addition of humus compost improves both clay and sandy soils.** Composted manure, rich in organic matter, may improve soil structure, but probably to a lesser extent than humus compost. Organic matter worked into soil helps it retain water and nutrients. The improvement in soil structure, causing soil particles to clump together, helps to prevent erosion of sandy soils and water runoffs and the drying out of clay soils. Compost also stimulates soil microbes, such as fungi and bacteria, and earthworms, which recycle nutrients for plant use. Unlike manure, which rapidly stimulates soil microbe activity, humus compost activates microbes and earthworms slowly without harming plants. Properly prepared humus compost helps fight soil-borne pathogens that cause plant diseases.
  - **Humus compost, compared to manure, is low in nutrient content.** In time, however, microbes and earthworms generate nutrients from compost. **It is also more difficult to generate humus compost**

5) Compost Making

Manure vs. Humus (Plant) Compost

- **Manure:**
  - **Composted or aged manure is a rich source of nutrients and beneficial bacteria. It is high in nitrogen (N), phosphorus (P), potassium (K) and other micronutrients, which are released slowly for use by plants.** Unlike synthetic fertilizers, manure also improves the structure and water retention of soil, depending on the content of humus matter in the manure. **Besides the use of manure as soil fertilizer, it also aids in composting plant material.** The high content of nitrogen in manure activates soil bacteria that decompose humus matter.
  - **Fresh manure releases ammonia and nitrogen compounds, which can burn plant roots and kill seedlings. The microbial activity stimulated by fresh manure may be so strong that it also burns up and volatilizes the nutrients in the manure, depriving plants of nutrition**. Fresh manure also may contain pathogenic bacteria, such as Escherichia coli, often referred to as E. coli, which can affect human health. Avoid pathogenic bacteria and viruses by using only manure from plant-eating animals instead of fecal matter from dogs, cats and farm animals that feed on diets supplemented with meat products.

8

Important!
Never prepare organic compost with:

Cat or dog excrement which can carry diseases and make people sick.

Weeds with seeds that contaminate the ground.

Toxic plants (like eucalyptus leaves, walnut leaves) which prevent the growth of other plants.

Plants treated with herbicides.

Scraps of infected plants.

Poisonous plants.

Glass, metal and plastic, materials that do not de-compose.

Leftover fats and meats that decompose very slowly and produce a stench.

One way is to make a compost heap ...

Once you have enough manure, vegetable scraps and kitchen leftovers, you can start an organic compost heap Note: (1 inch = 2.5 cm & 100 cm = 1 m)

Choose a place that stays dry and sunny ; loosen the soil 30 cm to 60 cm deep, without tilling.

Bury a two-metre-high pole in the centre. Place the first layer of straw or dry stems on the loose soil.

Without flattening the under layer, add a layer of kitchen and vegetable scraps.

Sprinkle a small amount of ash or lime to avoid bad odours when the decomposition starts.

Make the next layer with manure.

Then add another layer of soil. The heap has to be watered daily.

Keep placing more layers in the same way

"Remember that the compost heap shouldn't be more than 1.50 m. or less than 75 cm. high."

When the heap has quite a lot of layers and has reached a height of approximately 1.50 m (4-5 feet):

- The compost heap should be covered with 3 cm (>1 inch) of soil or sand and then covered completely with a layer of straw (mulch).

- Finally, water the heap and remove the pole, which will leave a vent for aeration. Although you may have more material, do not continue adding it to the heap. Prepare another compost heap instead.

You should take care of your compost! The moisture and ventilation have to be maintained

Within a few days, there will be a great deal of activity in the heap you have prepared.

The microorganisms are transforming the scraps into fertilizer.

Don't forget to make sure that the microorganisms have plenty of air and moisture to do their work!

Some suggestions for taking care of the compost

1- Two or three days after having prepared the compost heap, you should stick your hand into it to make sure it is hot.
If the mixture is just lukewarm, you have to add water.
2- If, when squeezing a handful of the mixture:
- drops of water are released, it means that there is enough moisture.
- water runs out, it means that there is too much moisture.
- nothing comes out, it means that it lacks moisture.
3- In hot weather, the compost heap needs to be watered every day so that it does not dry out.

Compost needs special care

4- If the heap is in direct sunlight, it has to be protected with branches.

5- In case of too much rain, cover the heap with plastic or old sheeting.

6- After three weeks, turn the compost over with a rake or shovel. Repeat this procedure every 10 days to aerate better.

After three months, the compost will be ready!

t 8

The finished compost:

- has a pleasant odour of soil and leaves.

- is very dark in colour.

- is unrecognizable from the materials that had been placed in the heap.

How is compost used?

55

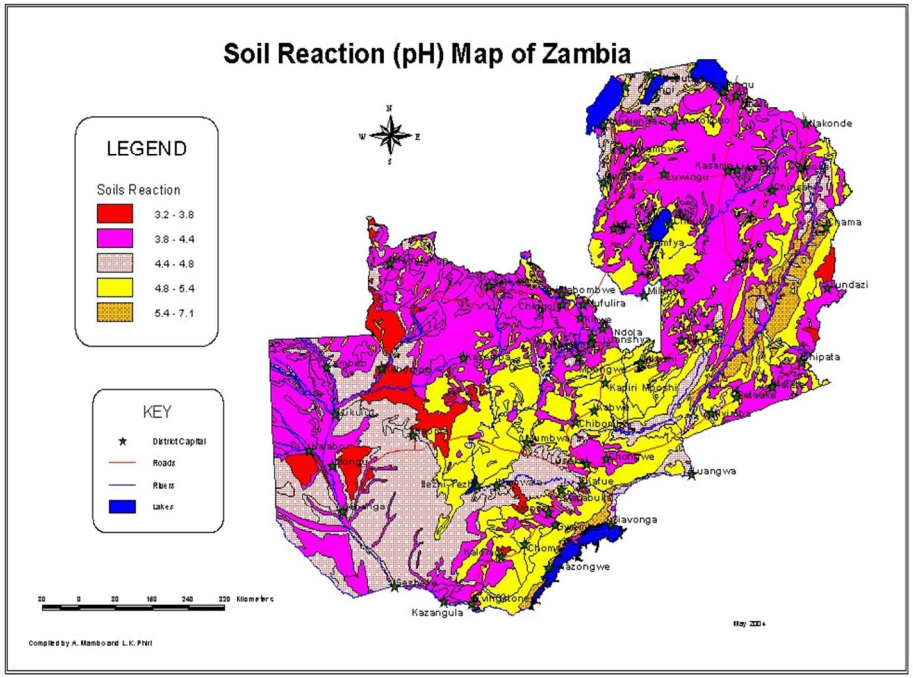
You need about 30 kg of organic compost for every 10 square metres of garden. A 1-metre -high compost heap provides approximately 70 to 90 kg of compost.
Note: 10 m2 = approx. 108 ft2

1 kg = 2.2 pounds

6) Green Manure

- Green manure refers to a techniques to plough the plant in the soil without harvesting it. The plant is broken down in the soil to be a fertilizer that supplies organic matter to the plant to be cultivated later.
- Improve soil fertility (ex. clover, sorghum, marigold, and sunhemp). It also acts pest controller during cultivation as cover crop and banker plant
- EXTENSION OFFICERS' MANUAL (Prepared by RESCAP) explains use of Sunhemp and Tithonia as green manure

How to apply tithonia as green manure

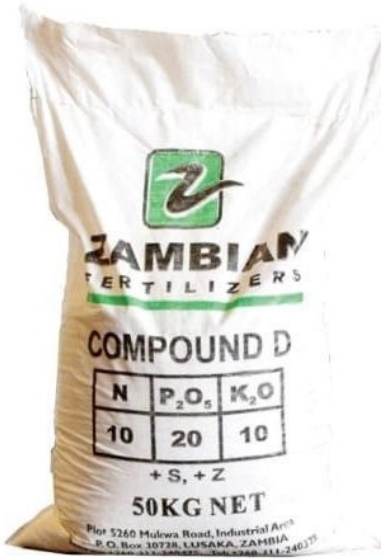


7) Control of Soil Acidity

- In Zambia approximately 40 % affected by soil acidity
- A large part of the project area is categorized as acid soil (pH 4.4 or less)
- Optimum nutrient uptake by most crops occurs at a soil pH near 7.0. The availability of fertilizer nutrients such as nitrogen, phosphorus and potassium generally is reduced as soil pH decreases. Phosphorus is particularly sensitive to pH and can become a limiting nutrient in strongly acid soils. Thus, reduced fertilizer use efficiency and crop performance can be expected when soil acidity is not properly controlled. Soil pH also affects the types, concentrations and activities of soil microorganisms. As pH drops below 5.5, the population of soil microbes changes and is reduced due to aluminum and manganese toxicity and reduced nutrient availability. Fungi tend to become more prevalent in acid soils because they better tolerate acidity compared to bacteria.
- **Application of lime is a quick measure (ash also has similar effect)**
- Selection of crops that are relatively tolerant to acid soil (Irish potato, S-potato, watermelon, maize, pumpkin, eggplant, and tomato)

7) Fertilization (use of inorganic fertilizer)

- Fertilizers are either organic or inorganic. Examples of organic fertilizers include manure (poultry, cow or horse), bone meal, cottonseed, or other naturally occurring materials. Inorganic fertilizers are man made products. They usually have a higher nutrient content.
- The three numbers on fertilizer containers are the fertilizer analysis. They indicate the percent of nitrogen, phosphorus and potassium in the fertilizer, respectively.



7) Fertilization (use of inorganic fertilizer)

- These figures are always listed in the same order. So, a 50kg bag of 10-20-10 fertilizer contains 5kg of nitrogen, 10kg of phosphorus, and 5kg of potassium. This equals a total of 20kgs of nutrients. The rest of the fertilizer, or 30kg in this example, is a carrier or filler such as sand, perlite, or rice hulls. A complete fertilizer is one that includes all three elements.
- When you buy fertilizer, consider the cost per kg of the nutrient(s). Generally, higher analysis fertilizers and larger containers are less expensive. For example, a 50kg bag of 10-20-10 may not cost any more than a 50kg bag of 5-10-5 fertilizer, but the 10-20-10 bag contains twice the nutrients.
- When designing fertilization, consider nitrogen (N) mainly, which is the most important required the mot in quantity for plants. Determine amount of fertilizer to apply based on the percentage of nitrogen in your fertilizer and your fertilizer recommendation.

7) Fertilization (use of inorganic fertilizer)

- Now a farmer wants to apply 150g of N per $10m^2$ using 10-12-8 fertilizer. The fertilizer contains 100g of N per 1kg (1kg x 10% =100g).
- Since the farmer wants to apply 150g of N,

  Necessary amount of fertilizer = 150g / 10% = 1,500g = 1.5kg
- Thus the farmer need to apply 1.5kg of the fertilizer per $10m^2$ in order to apply 150g of N.
- The 1.5 kg of the fertilizer includes,

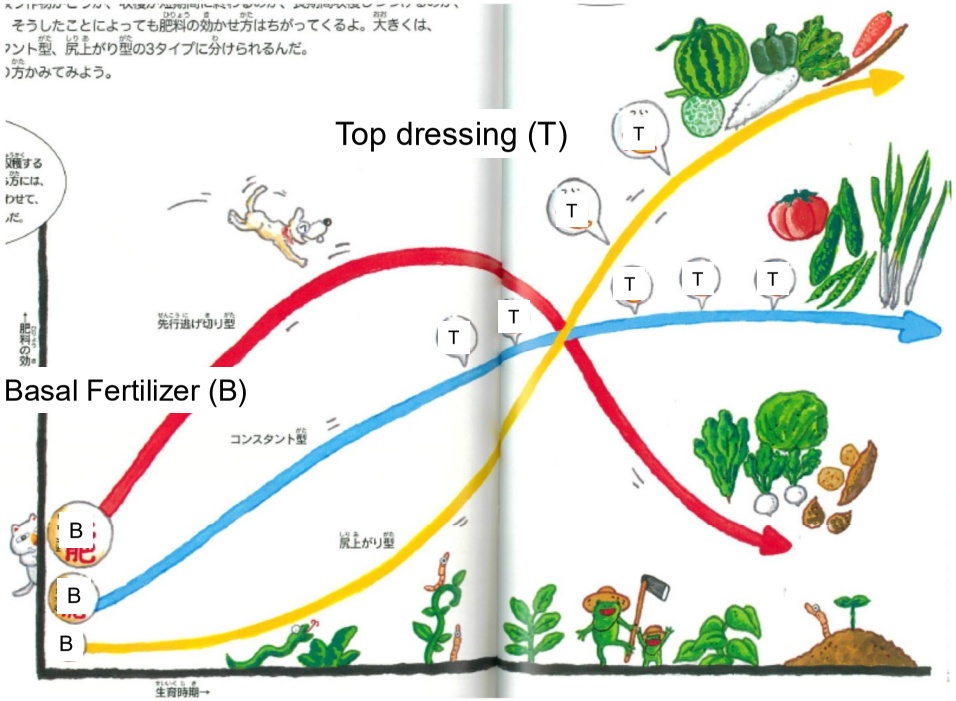
  P: 1,500g x 12% =180g

  K: 1,500g x 8% =120g
- Therefore, if the farmer apply 1.5kg of the fertilizer, she/he apply 150g of N, 180g of P, 120g of K per $10m^2$.
- All parts of a plant need nitrogen for growth—the roots, leaves, stems, flowers and fruits. Nitrogen gives plants their green color and is needed to form protein. A lack of nitrogen causes the lower leaves to turn yellow and the whole plant to turn pale green. On the other hand, too much nitrogen kills plants.
- Phosphorus is needed for cell division and to help form roots, flowers and fruit. Phosphorus deficiency causes stunted growth and poor flowering and fruiting. P is highly required during the early stages.
- Plants need potassium for many of the chemical processes that allow them to live and grow. A potassium shortage shows up in various ways, but stunted growth and yellowish lower leaves are common symptoms in many plants.

7) Fertilization (use of inorganic fertilizer)

- Amount of fertilizer components required largely depends on types of crops. The timing for application also varies depending on the cultivation methods and duration.
- The amount of nitrogen required by plants is around 5% of the dry weight of organizations (stems, leaves, flowers, fruits, etc.) have been made by the plant after the last fertilization.
- Application of fertilizer depends on following points;
  - Types of vegetables
  - Vegetables whether a farmer harvest leaves, fruits or stems, roots,
  - Vegetables whether absorb the fertilizer very well or not
  - Harvesting period (harvest once or several types)
- Please look at a following picture

Understand nature of your vegetable



7) Fertilization (use of inorganic fertilizer)

- (Yellow chart) Watermelon, Melon, Pumpkin, radish needs less fertilizer at the beginning of the growth, but requires enough fertilizer to grow its roots and fruits from the middle to the end of growth stage. Long matured and short harvest vegetables follows this pattern. This type requires a little basal fertilizer and needs enough top dressing.
- (Blue chart) Tomato, Cucumber and Eggplant which enlarges fruits while growing leaves and requires long harvest period and long growth. Vegetables such as Leeks and Celery needs constant application of fertilizer. At the beginning of the growth, a farmer should grow their roots by application of P. Then from the middle to the end of their growth, she should apply fertilizer constantly by top-dressing.
- (Red chart) Spinach, Rape, Chinese cabbage flourish stems and leaves and are harvested during vegetative growth stage. Their growth period is short and can be harvested once. They needs enough fertilizer from the beginning.

E-COBSI

Expansion of COmmunity-Based Smallholder Irrigation Development Project

Module 6: Cultivation Technics for Horticulture Crops (cont'd)

Popular Crop selected by SHEP Farmers:

Tomato Cultivation



Contents

1) Introduction
2) Cultivation Environments
3) Cultivars Choice
4) Field Management
5) Pest and Disease Control

1) Introduction

- Tomato originated from Americas.
- Introduced to Europe during the 16th century, later to many parts of the world.
- Currently, one of the most cultivated vegetable around the world.
- Solanaceous fruit vegetable.
- In Zambia both the ordinary and cherry types are cultivated.
- Can be grown all year round, but the cool season produces the best crop.

1) Introduction (cont'd)

- In winter the crop has very few pests and disease problems, compared to summer and rainy season crop.
- During rainy season, Rain-Shelters for Tomato Production is necessary (please see attachment)
- Yields are highly influenced by season.
- The period to maturity also depends on cultivar and season.
- Good source of vitamins: A,B1,B2,B3, and C,
- Also source of mineral; calcium ,phosphorus and iron

2) Cultivation Environments

Temperature

- Grow well in temperature range of 18℃ to 29℃.
- Experience dormancy under 10℃ and does not form fruits under 13℃.
- Meanwhile, high temperature causes failure of the pollination and low yield.

Soil Condition

- Soils-wide range, sandy soils or muddy soils.
- Free from nematode and soil diseases.
- Soil pH 6.0 -7.0. If pH is below 5, liming is recommended.
- Irregular moisture supply also causes poor setting, blossom end rot and fruit cracking in tomato.
- High temperature accompanied by low humidity, dry winds as well as high rainfalls are detrimental to tomatoes.

2) Cultivation Environments (cont'd)

Cultivation Season

- The crop can be grown all-year-round. But cool season performs better
- Nursery sowing- March and April transplanting yields best results. Sow 4-6 weeks before expected date of transplanting.

3) Cultivars Choice

- The yields for cool season higher than hot dry or rainy seasons. Due to favorable temperatures and low incidence of pests and diseases.
- Average fruits yields range from 25 to 50 tons per hectare in Zambia.
- However, smallholder farmers do not reach 10 tones per hectare due to poor cultivar choice, irrigation practices, plant nutrition, and pest and disease control.

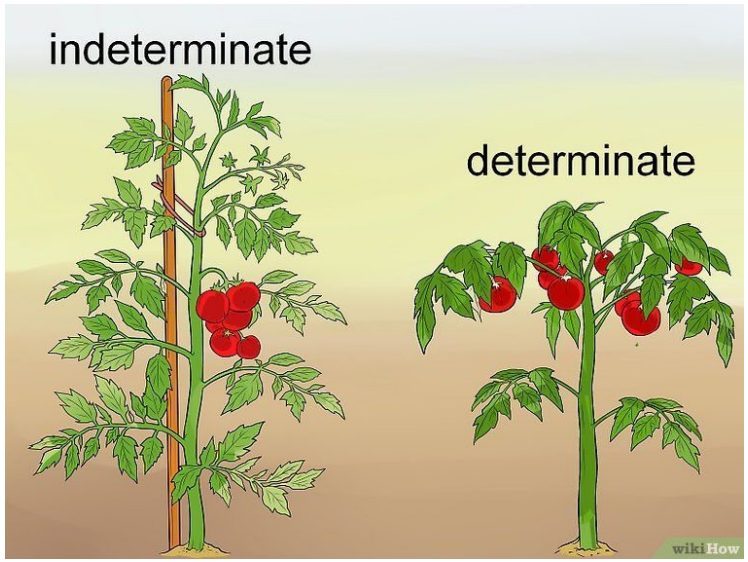
3) Cultivars Choice (cont'd)

Average yield and Maturation period in Zambia

Cultivar	Average Yield (Mt)			Maturation Period (days)		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Heinz 1370	48	25	14	106	115	95
Tengeru						
Rodade						
Herald	61	25	18	106	119	97
Moneymaker	47	22	13	109	120	92
Newton						
Red Khaki	55	30	15	105	117	91
Roforto VFN	54	25	12	108	115	92
Roma VF	51	25	22	107	110	91
Rossol VFN	51	27	14	107	117	90

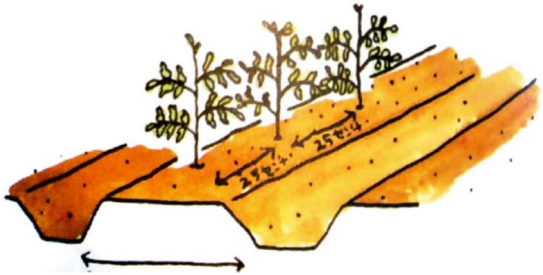
3) Cultivars Choice (cont'd)

Difference between determinate and indeterminate



4) Field Management

①Land Preparation



30cm

Spacing

- 90 x50 cm short varieties (determinate)
- 120 x 50 cm for taller varieties (indeterminate)
- Hight of the bed should be around 15cm to 20 cm
- Cultivate the soil to **the depth of 30 cm**

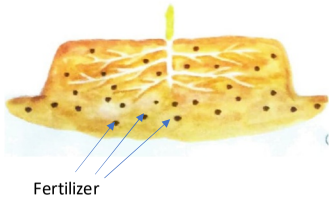
Basal Fertilizer

- 12 × 50kg bags of compound "D" per hectare
- Well decomposed livestock manure or compost at 1.5 to 3 kg/m^2

4) Field Management

①Land Preparation

(Basal fertilizer, Broadcast Application)



i. After application of lime and manure, land should be ploughed. Then, fertilizer will be broadcasted.

ii) Mix soil with fertilizer

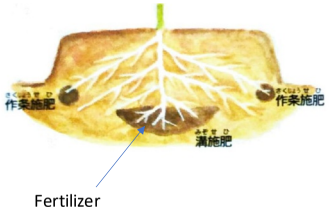
iii) Make a ridge (bed) after one to two weeks

iv) level the ridge (bed) and finish

4) Field Management

①Land Preparation

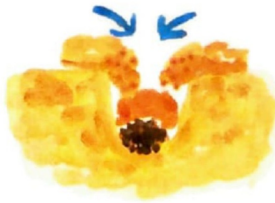
(Basal fertilizer, Band placement)



i. Line the middle of the ridge and

ii) Put manure, fertilizer and lime.

iii) Mix them and cover by soil



iv) make the ridge (bed) and level it

4) Field Management

②Nursery establishment and transplanting

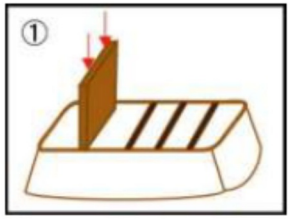
Seedbed Preparation

A fine seedbed is indispensable to make strong seedlings. You should choose a well-drained and un-shaded area. Dig soil deeply and break large clods. Weeds should be removed so that seeds are planted in a clean field. Seedbed should be raised to 20~25cm high.

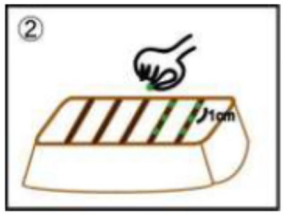
Burning the straw on the seedbed can help sterilize the soil. After that, apply 3-5kg of well decomposed manure per m^2 and mix it with soil thoroughly.

②Nursery establishment and transplanting

One by one sowing method

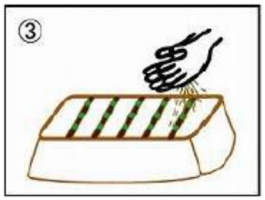


Make furrows by using the piece of timber. The spaces between rows are 10 to 15cm. these furrows enable uniformly water supply and germination.

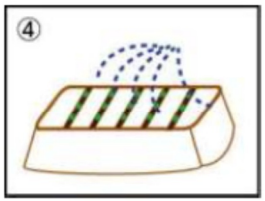


Sow the seeds one by one. The space should be 1cm between the seeds.

②Nursery establishment and transplanting



Cover by fine soil. Be careful not to sprinkle the soil too much on the seed. The amount of the soil should be 3 times as thick as the size of the seeds.



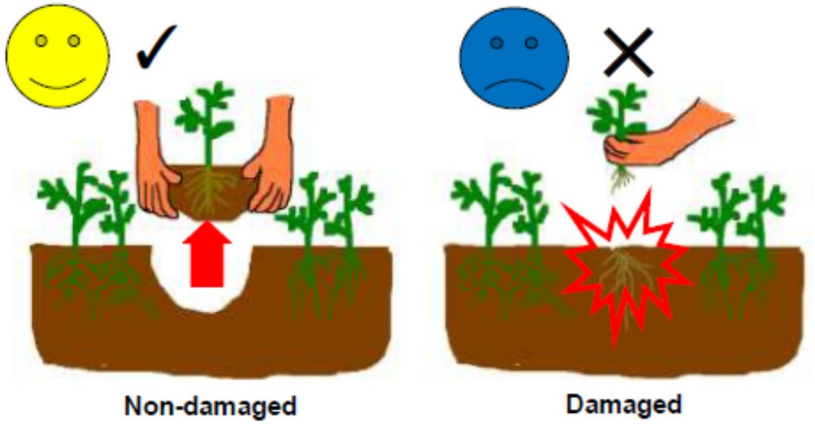
After making the roof on the seed bed, tenderly watering should be done. The roof is important to avoid strong sunshine/heat and washing the seed away after watering. The roof will be removed gradually after the germination.

②Nursery establishment and transplanting

4) Field Management

②Nursery establishment and transplanting

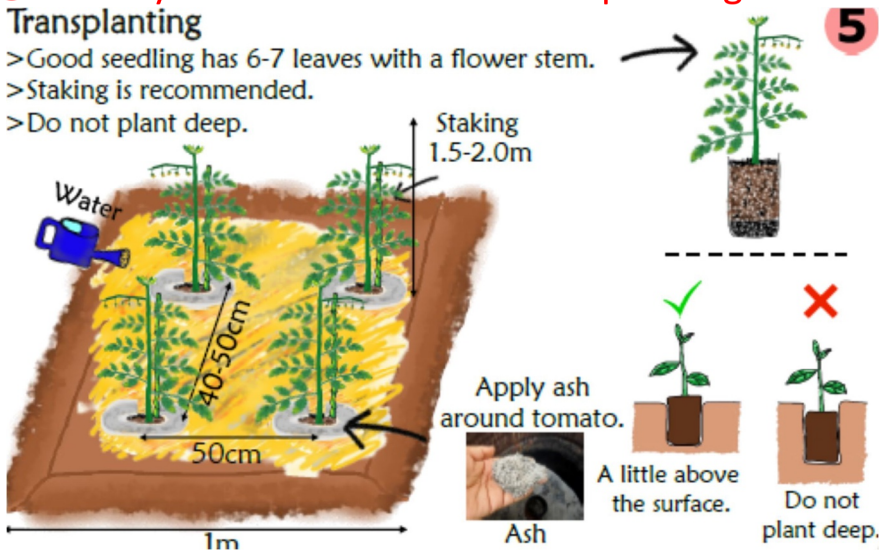
- After 4 weeks of sowing, transplanting should be done. Enough watering before 12 hours of transplanting is necessary. **Transplanting is done either early in the morning or late in the evening or on a cloudy day** minimize the shock of transplants. It is important to transplant with soil. If the roots are damaged, the plants get weak or die after the transplanting.



Non-damaged Damaged

4) Field Management

②Nursery establishment and transplanting



4) Field Management (cont'd)

③Staking

- Stake them when they are about 15cm high.
- It's done to avoid the foliage and fruit from touching the soil,
- staking materials are sticks.
- Tie the plants routinely to the stick with twine as they grow.
- Never grow tomato without staking in the rainy season in Zambia.

4) Field Management

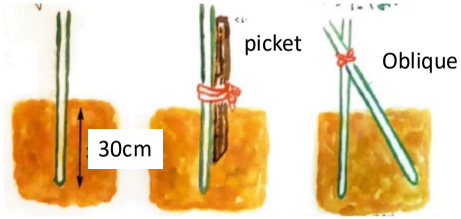
③Staking

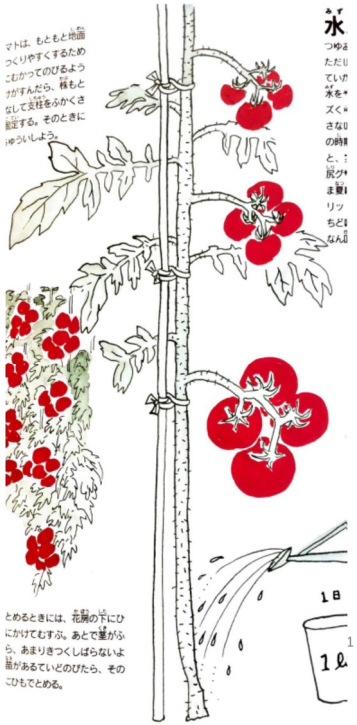
Staking

As tomato plants grow, staking is needed. Staking tomato plants with bamboo or wood stakes protect plants from being in contact with the ground. It can also increase the fruit yield and size, reduce fruit rot.

When you tie the plant to the stake, the knot should be loose to leave enough space for the stem to grow.

③Staking





4) Field Management (cont’d)

④Irrigation

- Irrigate immediately after planting to set the roots.
- Thereafter, the field should be irrigated daily for 5-7 days until the plants remain turgid most of the day.
- Thereafter, the regular irrigation interval of 7 or 10 days could be followed.
- When the plants are at the flowering and fruiting stage, furrow, flood, or drip rather than overhead irrigation is recommended, as the latter increases the incidence of foliar and fruit diseases.
- Do not use sprinkler irrigation as it might encourage blight (early blight and late blight) proliferation.

4) Field Management (cont’d)

⑤Pruning

・Pruning helps tomatoes direct its energy toward producing fruit rather than producing more foliage.

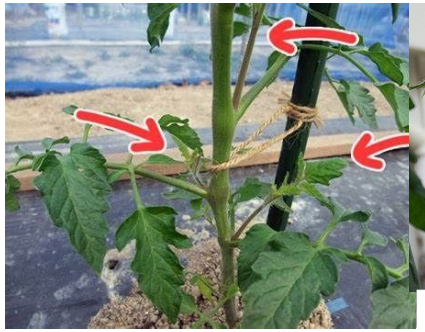
・When a tomato plant is pruned properly, all of the foliage receives adequate sunlight, and the plant is able to photosynthesize more efficiently, boosting growth and fruit production

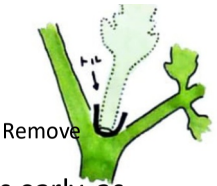
・Having too many flowering leave and off-shooting suckers will decrease production and slow down the plants ability to full ripen existing fruit.

・Pruning reduces incidences of pests and diseases because it improves ventilation and sunlight around tomatoes

4) Field Management (cont’d)

⑤Pruning



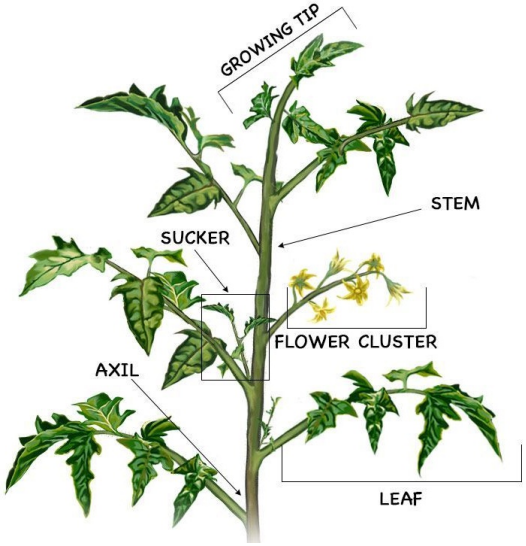


Start pruning your tomato plants early, as soon as there are flowers on the plants

4) Field Management (cont'd)

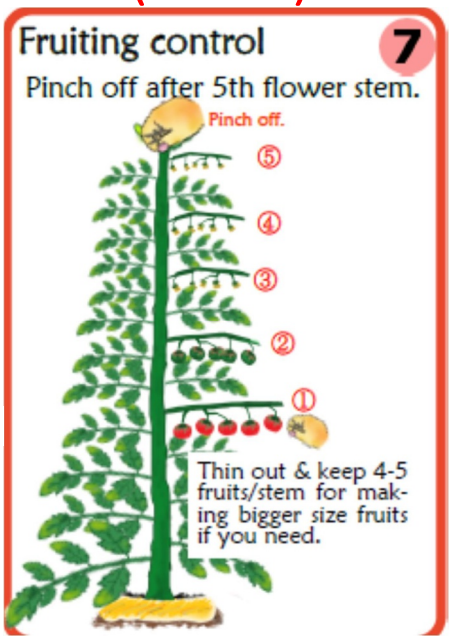
⑤Pruning

To remove the young suckers, you can use your hand to pinch them off. Pruning shears often infected the tomato plants. So, avoid using pruning shears unless the plant stem is too big to break down by hand. Razorblade is safer than other tools if you need to cut something from the tomato plants. If you touch the infected plants, please wash your hand and continue your work.



4) Field Management (cont'd)

⑤Pruning



4) Field Management (cont'd)

⑥Top-dressing

- 3 × 50kg bags of ammonium nitrate or 2 ×50kg bags of Urea per hectare
- 2 × 50kg bags of potassium chloride
- The top dressing should be applied in split doses, i.e., 2 weeks after transplanting and then a month after flowering.

4) Field Management (cont'd)

⑥Top-dressing

- Circular band around the stem or Row replacement; the fertilizer is applied in continuous bands on one or both sides of the row
- Top-dressing should be given at the center of roots as the plant grow
- After applying fertilizer, slightly plough the soil and mix fertilizer and soil while weeding

4) Field Management (cont'd)

⑦Weed control

- Weed control: Weeds help to create a humid environment that encourages the development of diseases. Remove weeds promptly b using appropriate weeding tools.
- Inter-cultivate to keep the field clean.
- Slight earthing up after top-dressing would help in getting rid of weeds at the time.
- Normally, scrapping before the irrigation when the weeds are still small is very effective.
- Chemical weed control could be done by using selective herbicides, such as Metribuzin or Treflan.

5) Pest & Disease Control

Insect (Pest)

- Some common insect pests include; **cutworms, fruit borers, aphids, grasshoppers, stink bugs, termites** and most recently, **Tuta absoluta**.
- The crop is also attacked by **red spider mites**.
- To control cutworms and any other insects, use systemic insecticides. Those might include Monocrotophos, Cypermethrin, Malathion, and others to treat insects. For red spider mites, use an acaricide, e.g. Tik tok, Abamectin. Other pests are nematodes (root knot type is common in vegetables).

5) Pest & Disease Control

Insect (Pest)

Tuta absoluta

Tuta absoluta is relatively new in Zambia, with the pest being reported with serious damages to the crop in 2016.

Tuta absoluta is easily found on tomato plants because it prefers the apical buds, flowers or new fruits where the black frass is visible.

When there is severe attack, it colonises the leaves on other part of the plants. Mines are evident on attacked leaves.

5) Pest & Disease Control

Insect (Pest)

***Tuta absoluta* : Control**

- Defection, correct identification (of pest and damage) and the use of threshold levels are key control of pests.

Methods in use:

Pesticides e.g. Denim fit, Emamectin benzoate, Abametin, organic pesticide like neem tree

Cultural methods e.g. use of Pheromone traps, destroying infected plants, crushing larvae, clearing

5) Pest & Disease Control

Insect (Pest)

Aphids

- 1-2 mm long aphids absorb the juice of tomato plants. It appears on the lower layer of the leaves. This infection causes stunting the plant, wreaking the plants and wrinkles the leaves.
- Body color varies from dark green to yellow green. The aphids parasitize young leaves of stems and flowers as well as lower leaves.
- This insect is a vector of a kind of mosaic virus and other viruses.
- Aphids may become resistant to insecticides due to the large reproduction potential and short germination cycle. Continuous application of the same insecticides must be avoided.

5) Pest & Disease Control

Insect (Pest)

Aphids **: Control**

- Remove the grass that these insects feed on.
- Keeping the soil nutrition balance among the nitrogen, potassium, phosphorus.
- Put insect traps (e.g. yellow pan trap) near the nursery. It should be set around the nursery to catch the insects.
- Apply recommended pesticide

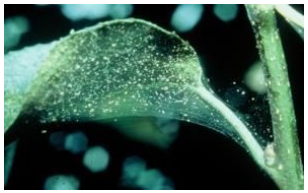
Pesticide	Amount
Confidate 35% SC	35 cm^3/100 litre of water
Confident 35% SC	75 cm^3/100 litre of water
Malet 35% SC	50 cm^3/100 litre of water

5) Pest & Disease Control

Insect (Pest)

Red Spider Mites

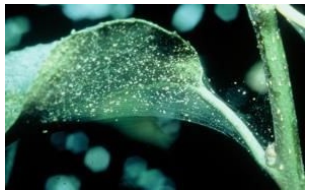
- Red spider mite feeds on the plant juice from the lower surface of tomato's leaves.
- The distinguished sign of infection is the existence of yellow spots turning into bronze scattered on leaves.
- In case of severe attack, leaves will dry and fall and we will be able to see the spider net on the lower surface of leaves or between plants. It also may get around buds causing its death.



5) Pest & Disease Control

Insect (Pest)

Red Spider Mites **: Control**



- Removing weeds and dry leaves.
- Apply the irrigation during high temperature period.
- Apply the potassium fertilization and the balanced fertilization.
- When the number of spiders more than 7 on the leaves, spray one of the following insecticides:

Pesticide	Amount
Agrimec Gold 8.4% SC	60 cm^3/ feddan
Acramite 48% SC	35 cm^3/ 100 liters of water
Excellent 1.9% EC	70 cm^3/ feddan
Overload 25% WP	400 gm/ feddan
Biomectin 5% EC	20 cm^3/100 liters of water
Gold 1.8% EC	40 cm^3/100 liters of water

5) Pest & Disease Control

Insect (Pest)

Nematode

- Growth of infected plants is retarded, leaves are small and yellow as if affected by fertilizer deficiency.
- Roots have numerous knots, leaves are wilting and dying.
- The attack of Nematode causes not only direct damage to plants but also expand the fungus disease which is in the soil.

5) Pest & Disease Control

Insect (Pest)

***Nematode* : Control**

- Utilization of animal dung, green manure and compost in soil.
- Crop rotation with ground nut, maize, sorghum and guinea grass to prevent nematode damage.
- Mix planting or crop rotation with marigold.

5) Pest & Disease Control

Disease

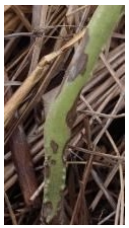
- The most common are fungal infections. **Foliar and fruit fungal diseases** may be prevented by fungicides such as Dithane M45, and treated by Benlate and Copper chloride. The resistant varieties are recommended to use, against some selected diseases.

5) Pest & Disease Control

Disease

Late blight

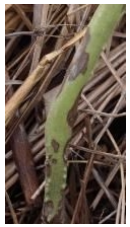
- This is *a* fungal disease.
- Symptoms include large necrotic areas around the edge of leaves, round blackish areas with pale purple blue zone.
- Attacks leaves, stems, fruits, and roots.
- Attacks around April to May.
- This disease occurs especially under cool and high humidity conditions in rainy season.



5) Pest & Disease Control

Disease

Late blight **: Control**



- Use the resisted variety and apply cropping pattern. Tomato and potato are not cultivated consecutive.
- Removal of infected parts as soon as it is found.
- For prevention, spray the following pesticide every 7-10 days: Dithane M45 80%E.P at 25g in 10ls of water or Daconil 75%W.P at 20g in 10ls of water, and Copper Oxychloride.

5) Pest & Disease Control

Disease

Early blight

- This is *a* fungal disease.
- Black spots appear on the old leaves of small plants.
- Spots extend and circle loops start to appear around its center, these spots look like an eye.
- Tissues around spots turn into yellow color.
- The high temperature and humidity condition expand the disease easily.
- Spots appear on the connection part of fruits with neck and stem and the infected fruits fall.
- Usually attacking from December to May .

5) Pest & Disease Control

Disease

Early blight **: Control**

- Apply cropping pattern, without repeating of tomato or same crop family of tomato e.g. Eggplant, Pepper and Irish Potato.
- Pick up the infected plants and burn it out of the filed.
- Apply the potassium fertilizer.
- Weekly applications of Dithane M45 80% WP 20g/30l water.

5) Pest & Disease Control

Disease

Powdery Mildew

- There appears a powdery substance on leaves.
- Infection appears on the surface of leaves in a shape of yellow spots and white spots on the opposite side.
- In case of severe infection these spots turning into brown and dry.
- The spots start to appear after 2 months from the cultivation but it depends on the cultivation season.

Control

- Copper based sprays could be used to control.

6) Pest & Disease Control

Disease

Bacterial wilt

- Bacterial wilt is caused by the pathogen bacterium Ralstonia solanacearum
- The pathogen is soil-borne and works its way quickly through the roots up the stem of the plants preventing water and nutrients from reaching the leaves and the plant wilts and dies very quickly
- Bacterial enters plants through wounds in roots made by cultivating equipment, nematodes, insects and cracks
- The vascular tissues of infected stems and roots turn brown, and in cross sections they ooze a whitish bacterial exudate
- Symptoms occur when the weather is hot and humidity is high. It is more common in soils with low pH (pH < 7.0).

Control

- Copper based sprays could be used to control.

6) Pest & Disease Control

Disease

***Bacterial wilt*: Prevention and Control**

Use of resistant variety:

- Plant resistant/ tolerant variety.

Cultural practices:

Before plantation:

- Consider an effective weed control (preventive, i.e. mulching) and mechanical weeding in and around tomato fields.
- Make 3-4 years rotation
- Use well drained and leveled fields,

Chemical control: use copper based fungicide has been found to suppress spread of disease in the field (e.g. Copper oxychloride)

6) Physiological Disorder

Blossom End Rot

- Blossom-end rot is caused by a calcium deficiency and is induced by deficiency of water in the soil.
- Hot, dry periods followed by large applications of water results in the plant not be able to absorb calcium quickly.
- Rapid plant growth, low potassium and calcium, excess magnesium and nitrogen, high salinity, root damage, and high relative humidity all predispose plants to Blossom-end Rot.
- Applying lime and manure to soil. Ensure adequate and consistent watering.

6) Pest & Disease Control

Disease

***Blossom End Rot* : Control**

- Applying lime and manure to soil.
- To avoid the heavy dry condition, ensure adequate and consistent watering.
- Careful irrigation in hot and dry season especially at fruit development stage.
- Balanced fertilization.