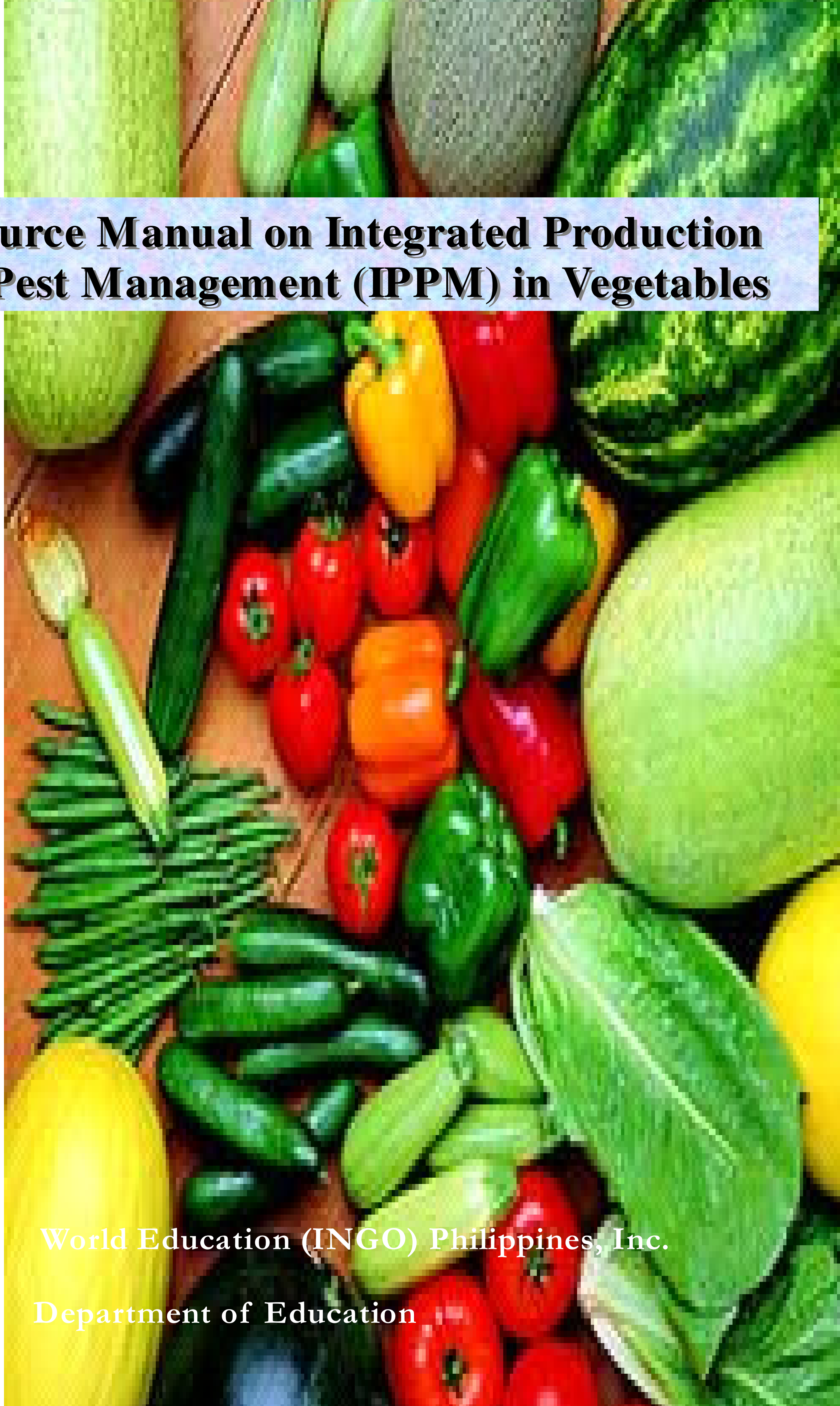

Resource Manual on Integrated Production and Pest Management (IPPM) in Vegetables

World Education (INGO) Philippines, Inc.

Department of Education

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Compiled and published by:

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FOREWORD

Vegetables are a rich and inexpensive source of vitamins and nutrients. Filipinos are major consumers of vegetables, and vegetable gardens are commonly found in the backyards of many Filipino households. Vegetable production is very popular in the Philippines. In fact, the Philippines is considered as the second largest vegetable producer in Southeast Asia including Australia. However, high vegetable production costs, for example of commercial fertilizers and pesticides as well as the unsustainable practices such as monocropping, make vegetable growing unnecessarily expensive and pose a great danger to our health and the environment.

This Resource Manual on growing vegetables using Integrated Production and Pest Management (IPPM) methods is part of a series of training and learning instruments developed and published by World Education (INGO) Philippines, Inc. This manual was produced to promote better understanding of the vegetable ecosystem as well as to teach the healthy and economical production practices for a particular vegetable crop.

The manual is a compilation of information on vegetable production that will facilitate growing vegetables using IPPM methods. The topics included here complement a set of learning competencies identified for IPPM in vegetable growing. The contents were put together from different sources and were carefully tailored to suit IPPM facilitators.

This was developed primarily as a reference for IPPM facilitators and is intended as supplementary material to facilitate and stimulate learning in a Field School.

The development and publication of this manual was made possible through the support given by the Royal Netherlands Embassy and the Philippines Department of Education (DepEd).

ACKNOWLEDGMENT

World Education (INGO) Philippines, Inc. would like to express gratitude to all the people involved in the development of this manual. The Royal Netherlands Embassy for the financial grant they have provided to develop and publish this manual. The Department of Education (DepEd) for reviewing the contents. To all the consultants who were involved in the review, editing of the contents and quality control of the manuals. The World Ed staff, who researched, compiled and laid-out the manual. Most of all, to the learners and facilitators of IPPM for whom the manual is intended for.

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PREFACE

This Resource Manual on IPPM ALS in Vegetables is a compilation of various documents on the production of commonly grown vegetable crops.

This was developed basically for the facilitators and learners of the Children's Participation in Integrated Production and Pest Management (CP IPPM) Program and the Integrated Production and Pest Management for the Alternative Learning System (IPPM-ALS) Program. The objective of this resource manual is to provide them a ready reference to complement the learning process in discovery-based IPPM ALS Session Guides that trainers will use in conducting FFS. It is intended to provide the "theoretical part" of IPPM.

The technical contents of this Resource Manual were taken from various documents produced by the National IPM Program (KASAKALIKASAN), FAO Rice and Vegetable IPM Programs in Asia, the AVRDC and Agricultural Universities. Many of the information were also downloaded from the internet.

It should be remembered that learning IPPM is best achieved through experiential learning process and cannot be mastered through books or references. The field is the primary source of learning. The field is the book. Hence, this manual is not to be used as an excuse for facilitators to give lectures to farmers or learners. Rather, this manual should provide facilitators with a reference guide in developing discussions that will enhance critical and analytical thinking among those participating in an FFS.

The Resource Manual has been divided into twelve chapters: **Part I** – ***Overview of Vegetable Production in the Philippines*** provides recent statistics and the state of vegetable production in the Philippines; **Part II** – ***The Ecosystem*** contains general concepts about the ecosystem and its components; **Part III** - ***The Living Soil*** discusses the characteristics of soil including composting and soil analysis; **Part IV** – ***Plant Parts, Functions and Seed Development*** talks about the functions as well as the development of seed until the seedling stage; **Part V** – ***Families of Vegetable Crops*** presents basic information and description of the families of vegetable crops included in this manual; **Part VI** – ***Production Guide for Selected Vegetable Crops*** consists of the production practices for selected vegetable crops; **Part VII** – ***Insects, Spiders, Common Pest of Vegetable Crops and Their Management*** shows and describes living organisms found in the vegetable field such as insects (pests and beneficial) and spiders particularly highlighting the roles they play in the ecosystem; **Part VIII** – ***Common Diseases of Vegetable Crops and Their Management***, discusses the common diseases of vegetable crops and their management; **Part IX** – ***Weeds and Weeds Management*** includes the description of weeds, weed types and their management; **Part X** – ***Pesticide Hazards*** contains information about various types of pesticides, their harmful effects to humans and the environment as well as the types of pesticide poisoning and their symptoms; **Part XI** – ***Post Harvest Processing of Vegetable Seeds*** includes topics on harvesting practices, seed storage methods and seed processing techniques; and **Part XII** – ***Farm Record Keeping*** provides information on how to handle farm records, how to conduct farm inventory and how to valuate farm properties. A "***Glossary***" section has been added at the back of this manual for further reference.

SOLANACEOUS

1. Bacterial soft rot - collapsing fruit in the field

2. Bacterial soft rot - collapsed fruit in the field

3. Bacterial soft rot - post harvest softening of the stem end

4. Bacterial spot - individual and coalescing lesions and leaf chlorosis

5. Bacterial spot - leaf and stem spotting causing leaf drop

6. Bacterial spot - slightly raised corky, dry lesions on the fr

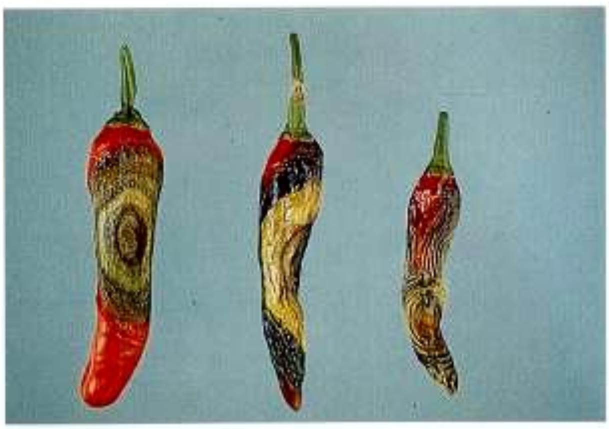
7. **Bacterial wilt -**
wilted plant with little or no yellowing

8. **Bacterial wilt -**
vascular discoloration in lower stem and roots

9. **Bacterial wilt -**
bacteria streaming from vascular system in the lower stem: a diagnostic method

10. **Anthracnose -**
sunken circular lesions with dark fungal growth and pink spore masses on ripe fruit

11. **Anthracnose -**
sunken circular lesions with pink spore masses on green fruit



12. **Anthracnose -**
elliptical lesions on elongate green and ripe fruit

13. Cercospora leaf spot (Frogeye) - gray-brown circular lesions with light colored centers

14. Cercospora leaf spot (Frogeye) - extensive leaf and stem spotting

15. Choanephora blight - tip die-back and fungal sporulation on a lateral branch

16. Choanephora blight - tip die-back of several lateral branches

17. Damping-off - pre-emergence and post-emergence seedling death

18. Root rot - stunted plants in nursery bed

19. Root rot -
root decay and collar rot

20. Phytophthora blight -
crown and stem rot causing total plant collapse

21. Phytophthora blight -
stem, leaf, and fruit symptoms due to above ground infections

22. Phytophthora blight -
plant death in a low, wet area of a field

23. Powdery mildew -
fungal sporulation and symptoms on the lower leaf surface

24. Powdery mildew -
chlorotic blotches on upper leaf surface opposite patches of sporulation on the lower surface

25. Stem rot (Southern blight) -
a suddenly wilted plant with little or no leaf yellowing

26. Stem rot (Southern blight) -
collar rot with superficial white mycelium and sclerotia at soil surface

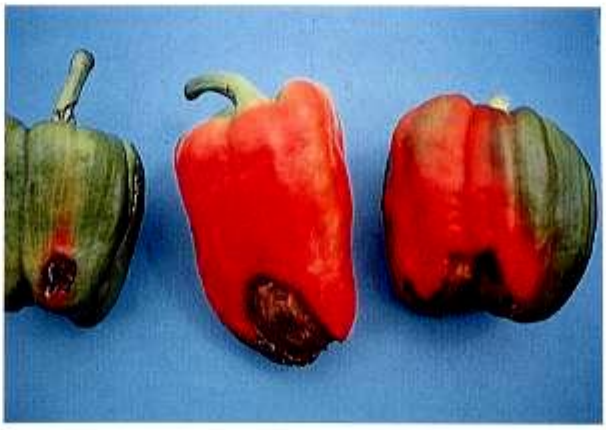
27. Sclerotinia stem blight (White mold) -
above ground, light tan colored stem lesion

28. Sclerotinia stem blight (White mold) -
split stem showing sclerotia in the pith

29. Gray mold -
stem lesion and decayed leaves showing fungal sporulation

30. Gray mold -
rotted fruit showing fungal sporulation

31. Root-knot (nematode) -
damaged root system showing numerous small galls typical of root-knot on pepper



32. Blossom end rot (physiological) -
dry lesions on the lobes of bell-shaped fruit

33. Blossom end rot (physiological) -
dry lesions near the blossom end of elongate fruit

34. Sunscald (physiological) -
light colored, papery lesions on the exposed fruit surface

35. Chilli veinal mottle (CVMV) -
distinct leaf mosaic pattern with dark green veins

36. Cucumber mosaic (CMV) -
leaf mosaic, narrowed leaves, and pale green foliage

37. Pepper mild mottle (PMMV) -
mild mosaic in leaves

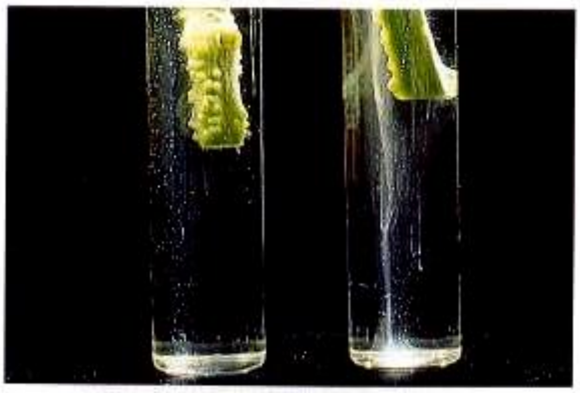
38. Tobacco mosaic (TMV) -
severe mosaic and yellowing of leaves

39. Tomato spotted wilt (TSWV) -
chlorotic and nectrotic ringspots on leaves

40. Chilli leaf curl (virus) -
small cupped leaves with marginal and interveinal chlorosis

1. **Bacterial wilt - a suddenly wilted plant with little or no yellowing; in the field**

2. **Bacterial wilt - a suddenly wilted plant with little or no yellowing; in the greenhouse**



3. **Bacterial wilt - bacteria streaming from vascular system in the lower stem: a diagnostic method**

4. **Bacterial spot- individual and coalescing leaf spots resulting in chloroisis and leaf blighting**

5. **Bacterial spot- fruit and stem spots and blighted foliage**

6. **Late blight - large rapidly expanding leaf lesions**

7. **Late blight - rough, firm fruit lesions**

8. **Late blight - extensively blighted foliage in the field**

9. **Buckeye fruit rot - smooth, firm lesions with concentric light and dark brown rings**

10. **Fusarium wilt - yellowing and blighting of foliage from the bottom up**

11. **Fusarium wilt - red to brown vascular discoloration**

12. **Leaf mold - upper surface with chlorotic spots, lower surface with olive-green to brown fungal sporulation**

13. **Leaf mold -**
blighted lower foliage on plants

14. **Black leaf mold (Cercospora leaf mold) -**
gray to black sporulation mainly on the lower leaf surface

15. **Black leaf mold (Cercospora leaf mold) -**
leaf rolling and black fungal sporulation

16. **Early blight -**
leaf lesions composed of concentric rings and associated leaf chlorosis

17. **Early blight -**
leaf and stem lesions and blighted foliage

18. **Early blight -**
dark colored fruit lesions consisting of concentric rings near the peduncle

19. Gray leaf spot -
small, circular gray leaf lesions and associated leaf chlorosis

20. Gray leaf spot -
leaf spots, chlorosis, and blighted foliage

21. Anthracnose -
circular sunken fruit lesions with dark fungal stroma evident

22. Stem rot (Southern blight) -
a suddendly wilted plant with little or no yellowing

23. Stem rot (Southern blight) -
collar rot with superficial white mycelial growth and sclerotia near the soil surface

24. Powdery mildew (Leveillula) -
leaf yellowing and necrosis evident on the upper surface

25. **Powdery mildew (Leveillula) - chlorotic spots on the upper leaf surface with sparse fungal sporulation on the lower surface**

26. **Powdery mildew (Erysiphe) - abundant sporulation on the upper leaf surface**

27. **Root-knot (nematode) - severely damaged root system with xtensive galling**

28. **Tomato mosaic (ToMV) - mild mosaic in leaves**

29. **Potato X (PVX) and potato Y (PVY) - individual and combined effects on plant growth**

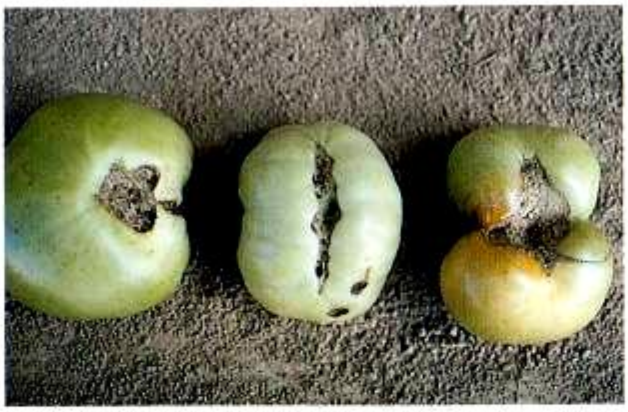
30. **Cucumber mosaic (CMV) - mosaic and leaf narrowing (shoestringing)**

31. Tomato spotted wilt (TSWV) -
mosaic and yellowing of foliage and severely stunted plant

32. Tomato spotted wilt (TSWV) -
chlorotic ringspots that become distinct as the fruit ripens

33. Tomato yellow leaf curl (TYLCV) -
small, cupped leaves with marginal and interveinal chlorosis

34. Blossom end rot (physiological) -
black, dry sunken lesions in the blossom end of the fruit followed by premature ripening



35. Catfacing (physiological) -
misshapen fruit associated with the blossom end

36. Gray wall (physiological) -
gray to brown sunken areas on the fruit surface and brown internal tissue in the fruit walls

E. Seed Treatments

Two reasons to treat seeds

1. To control diseases attached to or inside the seed (seed-borne diseases),
2. To protect seeds against diseases in the soil that can attack seeds, emerging roots or young seedlings (soil-borne diseases).

Seed-borne Diseases

Seed can become infected with fungal spores or bacteria (seed-borne diseases). Infection can accur during the growing season, when seed is still on the plant or it may occur after the seed has been extracted from the plant. Common seed-borne diseases of tomato are early blight (*Alternaria solani*), Tobacco Mosaic Virus (TMV) and fungal wilt (*Fusarium* and *Verticulum*).

Soil-borne Diseases

Seed can also become infected after it has been sown in the soil. Fungi or bacteria living in the soil may attack the seed and cause death of the seed or the emerging roots even before the seedling has emerged above the soil (soil-borne diseases). A common soil-borne disease affecting seed and seedlings is damping-off, caused by a complex of fungi.

When to Treat?

When seed is bought from reliable seed companies, it will usually be disease-free. When seed is locally produced, it is probably better to sterilize it before sowing. When soil has causes problems with damping-off disease before, it can be helpful to coat seed before sowing.

Seed Treatment Methods

There are four main methods for seed treatment:

1. Physical by soaking in hot water
2. Chemical by sterilizing seed with chemicals or coating seed with a layer of fungicide.
3. Botanical by coating seed with a layer of plant extract.
4. Biological by coating seed with a layer of antagonistic fungi.

None of these treatments will completely prevent attack in all circumstances. In addition to seed treatment, it is important to select a field that is free of soil-borne disease. Some management practices for soil-borne diseases include crop rotation and the use of resistant or tolerant varieties.

Hot Water Seed Treatment

To kill fungal spores or bacteria attached to or within the seed, seed should be soaked in hot water at 50^{O}C for 30 minutes.
The right water temperature and the right duration for seed treatment are very important. If the water is too cold, the pathogens are not killed. If the water is too hot, seed germination will be strongly reduced.

The easiest way to treat seed is to prepare water of 50^{O}C on a small fire or burner. Carefully check water temperature with a thermometer. Pour the 50^{O}C water into a thermos flask and add seed. It may be easy to wrap the seeds in a cloth to keep them together. Leave the seed in the flask for 30 minutes. After soaking in hot water, the seed is placed in clean, boiled water already cold, to cool down the seed. Dry by spreading the seed in a thin layer on paper or cloth.

In some cases, a fungicide coating is applied after hot-water treatment.

Chemical Seed Treatment

Many seed companies use chemical treatments, such as sodium hypochlorite or sodium phosphate, to sterilize the surface of the seed. Next to this, seed can be coated with a fungicide. This fungicide can sometimes be seen on the seed as a colored coating. The fungicide used is listed on the seed package. The fungicide can kill spores of diseases. Chemical fungicides for seed protection are relatively inexpensive and cause little environmental damage since they are used in small amounts. However, they are effective only for a short time (at most one month) and they do not spread through the soil with the root system.

Unfortunately, chemical seed sterilization cannot guarantee that the seed is completely disease free. This is because some pathogens are present inside the seed. An example is TMV where the virus can be present both on and in the seed coat. Chemicals only sterilize the surface of the seed and do not reach infections inside the seed. Hot water treatment may sometimes be more effective to control pathogens inside seed.

Botanical Seed Treatment

Seed can be protected from soil-borne fungi and from cutworms by a coating of a botanical extract such as crushed garlic. Garlic is well known for its strong odor which has repellent effect on insects and birds, and it can prevent diseases. The garlic is thoroughly crushed to obtain juice and pulp. Seed is mixed with this extract. The seed can be immediately sown after this treatment, or left to dry.

Biological Seed Treatment

Seed can also be protected with a coating of biological agents. These are usually antagonistic fungi or bacteria that work against soil-borne pathogens. Examples are the antagonist fungus *Trichoderma sp.* and the bacterium *Bacillus subtilis*, which are sometimes mixed with a chemical fungicide for commercial seed treatment.

The good thing about using this biocontrol agents as seed treatment is that they also provide protection of the roots that emerge from the germinating seed. This is because the antagonists grow and multiply in the area around the seedling roots. This way they suppress fungi that cause damping-off and root disease.

Sources:
Black, Lowell. Vegetable Diseases: A Practical Guide. Asian Vegetable Research and Development Center. Shanhua, Taiwan
FAO Inter-Country Programme for the Development and Application of Pest Management in Vegetable Growing in South and SouthEast Asia. 2000. Toamto Integrated Pest Mnagement : An Ecological Guide.
http://ag.arizona.edu/pubs/garden/mg/pathology/symptoms.html
http://entomology.montana.edu/extension/disea029.htm
http://www.apsnet.org/education/IntroPlantPath/Topics/plantdisease/

PART XII: FARM RECORD KEEPING

In collecting data through record keeping, request farmer cooperators to record their farm activities and transactions for a year. Daily record is ideal but experience shows that weekly recall and recording has been found to be satisfactory and more accurate. Information can be obtained through this method but there is a need to supervise the farmer cooperator and direct what is to be done on the recording of information. This makes a regular visit to the farmer-cooperator necessary.

A. Data to be Recorded/Collected

The farmer cooperator has to keep records and accounts. Farm records and accounts are written statements or collections of facts and figures on a subject for a definite purpose. The data to be included and the sequencing of the data or information depend on your purpose. They may include data on money, dates and events, or quantities of farm produce. Examples of these records are inventory record, farm sales, farm expenses, feed record, etc. Farm accounts, on the other hand, are written financial statements. Examples are fertilizers account, feed account, insecticide account, etc. Money values are included in these accounts from purchase records, fertilizer records, and insecticide records.

The form of record keeping that can be asked of the farmer-cooperators depends on the farmers' present skills and knowledge on record keeping. While records could be written on walls, posts, calendars, and pocket notebooks, it is preferable to let the cooperator do a single entry form, which is an improvement over the common practices that has been mentioned. The cooperator may be taught how to do the recording. The following are examples of single entry records.

Table 36. Single Record Entry Example No. 1

Sales Record				
Date	**Unit**	**Description**	**Unit Value**	**Total Value**

Table 37. Single Record Entry Example No. 2

Sales Record								
Date	**Unit**	**Description/ Quantity**	**Rice**		**Corn**		**Others**	
			Unit Value	**Unit Value**	**Unit Value**	**Unit Value**	**Unit Value**	**Unit Value**

B. Classification of Receipts and Expenses

Farm records have to be classified based on receipts and expenses. For example, records for sales include cash sales and value for marketed products. They should also show the date of transaction, quantity of products sold (for each product), price per unit and total receipts.

There should also be a record for miscellaneous receipts and non-cash income to take care of unclassified receipts and non-cash income, respectively. If applicable, expenses can be classified into fuel and oil, equipment repairs and maintenance, transportation, taxes and interest paid, capital expenditure, and miscellaneous. Likewise, there should also be a record for unpaid family labor and non-cash expenses.

C. Farm Inventory

Farm inventory, together with the farm and accounts, is also needed to summarize the farm business. There is also a need for the inventory data for the farm business survey method. The farm inventory is a list of what the farm business owns (assets) and owes (liabilities) at a given time, together with their values. The farm inventory may include the following categories:

a) Real estate (land and buildings)
b) Farm equipment and machinery
c) Feeds and supplies
d) Livestock
e) Growing crops
f) Others (cash on hand, notes receivable and accounts payable)

The best time to take the farm inventory is at the beginning and ending of a farm business year since less farm work is done at this time. The inventory is done by first listing down all farm properties and providing a brief description for each. The description may include the date of acquisition, construction or planting (in case of growing tree crops), original cost, number or quantity, etc. Then a value is placed on each item. All farm debts and receivables are also listed. Lastly, the information are summarized for farm business analysis purposes. The change can be computed for a given period using the following formula:

$$\text{Change in Inventory} = \text{End-of-the-Year Value} - \text{Beginning-of-the Year Value}$$

A positive value implies an increase in inventory while a negative value means a decrease in inventory.

The average inventory can be obtained using the following formula:

$$\text{Average Inventory} = \frac{\text{Beginning-of-the Year Value} + \text{End-of-the Year Value}}{2}$$

D. Methods of Valuing the Items in the Farm Inventory

The biggest problem in making an inventory is how to place accurate values to the items. So, farmers need to know the following terms:

1. **Original Cost** – the actual purchase of the asset. It is appropriate for assets with short life span whose values do not change very much through time.

2. **Normal Market Value** – the estimated average selling price of a project over a period of years

3. **Present Market Value** – the appropriate price for the property at the time of inventory

4. **Original Cost Minus Depreciation** – commonly used for properties that are used for several years

5. **Cost Value** – a method of valuing a forest stand that can be used to value the growing timber crops

Table 38. Suggested Valuation Method for Different Farm Properties

Farm Property	Suggested Valuation Method
• Purchased feeds and supplies	• Original cost
• Crops raised and homogeneous feeds	• Present market value
• Livestock for sale	• Present market value
• Breeding and work animals	• Normal market value
• Equipment and machinery	• Cost minus depreciation
• Growing tree crops	• Cost value or market value
• Buildings	• Cost (of construction) minus depreciation

E. Determining Depreciation

Depreciation represents the decrease in the value of a property due to normal wear and tear and obsolescence. The common ways of computing annual depreciation are:

a) Straight-line method
b) Declining balance method

c) Sum-of-the-years digit method

Straight-line Method

In the straight-line method, first estimate the life span and scrap value from the original purchase price. Determine the annual depreciation using the formula:

$$\text{Annual Depreciation} = \frac{\text{Purchase Price} - \text{Scrap Value}}{\text{Estimated Life Span}}$$

For example, the original cost of a farm implement is PhP 12,000. It has a life span of ten years and a scrap value of PhP 2,000. How much is the annual depreciation charge?

Solution:

$$\text{Annual Depreciation} = \frac{\text{PhP } 12{,}000 - \text{PhP } 2{,}000}{10 \text{ Years}} = \text{PhP } 1{,}000/\text{year}$$

Declining Balance Method

In the declining balance method, estimate the depreciation charge based on the original cost of the property, its life span and the percentage of the original cost to be charged for depreciation. Each year of use of the property reduces its estimation of the depreciation charge for the ensuing year. This method leaves a small, unrecovered balance at the last year of property's useful life.

Sum-of-the-Years-Digits Method

For this method, first determine the life span of the property. Then take the sum of the digits of the years, and use this as the denominator of each year's depreciation. For example, if the life span is 10, the sum-of-the-years-digits is 55 (10 + 9 + 8 + … + 1) This becomes the denominator.

This method assumes a heavy depreciation charge for the earlier years. To ensure this, the numerator for the first year takes on the value of the last year. It is just similar to a countdown, where we assign the last year, in this case 10, for year 1. We then arrive at a ratio where the numerator is what has been described before and denominator is the sum-of-the-years-digits. To get the depreciation charge per year, multiply the ratio by the original cost.

Source:

Cruz, C. A. and M. Calderon. ENRM 231: Economics of Upland Resources. University of The Philippines Open University. 194-201 pp.

PART I: OVERVIEW OF VEGETABLE PRODUCTION IN THE PHILIPPINES

The Philippines is the second largest vegetable producer in the whole of ASEAN including Australia as reported in 1999.

Agricultural crops valued at PhP276 billion in 1997 composed of 57 % from paddy, corn, coconut and sugarcane with the balance of PhP118.2 million accounted for by other crops led by banana, pineapple, mango, cassava, sweet potato, vegetables, coffee and other fruits. Agricultural trade statistics in 1997 show imports of US $3 billion and exports of US $2 billion. Principal exports are sugar, coconut oil, banana, pineapple in syrup, copra oil, desiccated coconut, tuna, coffee, and abaca (Manila hemp) amounting to US $1.4 billion. Other exports include asparagus, onion, processed tomato, mango in various forms, processed calamansi, banana chips, potato chips, coffee, melon, papaya, ube, jackfruit, cocoa beans, and brewed ginger and herbal teas.

Smallholders dominate the agriculture industry. Between census years 1971 and 1991, the average farm size is decreased from 3.6 to 2.1 hectares, the number of farms is increased from 2.3 million to 4.6 million, and the total area increased from 8.4 million to 9.9 million hectares. Temporary crop areas accounted for 76 % of total farms with the rest devoted to permanent crops composed mainly of coconut and fruit trees. The area planted with temporary crops was dominated by rice and corn (i.e.comprising 92%) and the rest was planted with other crops.

The implementation of the Comprehensive Agrarian Reform Program (CARP) has been a primary reason for the declining farm sizes. Some specialty crops lend well to the manageable farm sizes in the light of increasing labor cost and shortages during peak planting and harvesting months. However, critical volumes are required by processors requiring cooperatives to undertake bulk marketing and clustering to meet economies of scale under contract growing with large processors. The national program must address the need for producers' reorientation their production systems to the market to be competitive.

Fruits and vegetables, in particular, are a cheap source of healthy foods which have impact on the nutritional state of Filipino consumers. While there are specialty fruits and vegetables for the high end markets, there are more that can easily be grown for home consumption and or marketed to the average consumers. Food security may be the ability to produce or procure food. Growers have a wide choice of horticultural crops to establish food security and improve their income levels, Poverty alleviation may be addressed by expanding opportunities to earn incomes from farm productivity and or on farm and off farm employment. Food manufacturing and value adding activities near the production areas offer employment alternatives and livelihood opportunity.

The Philippines has produced 786,900 hectare of vegetables crops (Maghirang.1999). Table 1 shows some of the vegetable crops it produces including the total production and hectarage for each crop in comparison with other ASEAN countries. This is followed by two tables, which present the value (Table 2) and Agricultural (Table 3) production of these crops in the last three years.

Table 1. Production Records (in metric ton) and Hectarage of Vegetable Crops of ASEAN Countries (1999).

Commodity	Philippines		Thailand		Indonesia		Malaysia		Australia		Myanmar	
`	Prod'n	Hectare	Prod'n	Hectare	Prod'n	Hectare	Prod'n	Hectare	Prod'n	Hectare	Prod'n	Hectare
1. Cucumber	7,000	1,700	215,000	24,000	315,000	56,000	55,000	2,200	16,000	1,100	-	-
2. Eggplant	180,00	18,000	65,000	10,500	150,000	43,000	-	-	-	-	-	-
3. Garlic	19,300	7,700	131,403	24,500	62,607	14,870	-	-	-	-	61,770	16,000
4. Onion	85,358	11,911	-	-	-	-	-	-	-	-	-	-
5. Squash	72,420	8,500	205,020	17,000	149,960	23,000	14,085.9	470	104,995	8,300	-	-
6. Tomatoes	138,340	16,500	114,000	12,000	324,382	43,666	10,000	570	394,397	8,000	-	-

Table 2. Value of Crop Production in the Philippines

Item (in Million Pesos at Current Prices)	**2001**	**2002**	**2003**
Onion	2,230.5	1,153.4	1,595.0
Garlic	717.5	955.8	784.2
Tomato	1,564.1	1,026.8	1,827.6
Eggplant	2,078.6	1,742.7	1,851.5
Cabbage	714.5	887.1	746.9

Table 3. Agricultural Crop Production in the Philippines

Item (in '000MT)	**2001**	**2002**	**2003**
Onion	82.6	96.4	93.8
Garlic	15.4	16.3	15.5
Tomato	146.0	149.3	150.1
Eggplant	169.8	179.7	177.0
Cabbage	89.5	91.4	92.0

Sources:
http://www.bar.gov.ph
http://www.bas.gov.ph
http://www.da.gov.ph

PART II. THE ECOSYSTEM

An **ecosystem** consists of a number of living organisms and their physical environment. The living organisms and their non-living environment are interrelated and interact with each other. There is a flow of energy from the non-living organisms to the living organisms. There are a number of material cycles – that is, the exchange of materials between living and non-living elements of the ecosystem.

The ecosystem is also defined as the complex interaction between non-living/physical (**abiotic**) and living organisms (**biotic**). The earth in itself is an example of a functioning ecosystem.

An **Agroecosystem** is a unit composed of the total complex of organisms in an agricultural area in relation with the environment that may further be modified by the farmer's own agricultural practices.

The word agroecosystem traces its origin from Greek and Latin root words presented below.

Agro – Latin word "ager" which means agriculture
Eco – Greek word "oikos" which refers to house or the earth
System – means grouping of parts that function together as a whole

A. Components of the Ecosystem

The ecosystem is composed of non-living or abiotic and living or biotic components. Specific examples of each component appear below.

1. Non-living (Abiotic)

a. water
b. soil
c. climate
d. sun
e. temperature
f. inorganic/organic compounds
g. other physical factors

2. Living Organisms (Biotic)

a. **Producers** are plants and microscopic forms called phytoplanktons. They are plants, which have green leaves containing chlorophyll. They produce food (carbohydrate) for themselves and for all other living things by using sun energy and by absorbing nutrients (water, carbon dioxide, etc).

b. **Consumers** are animals which feed on producers. They are divided into 4 groups:
   1) Herbivores (first order) - insects that directly eat the products of producers
   2) Second order predators - natural enemies of herbivores, examples include spiders and frogs, parasites and parasitoids and microscopic entomophagus pathogens that consume mainly animals of the first order

3) Third order predators eat the second order predators, e.g. snake
4) Carnivores - eat mainly the animals of the third order, e.g. eagle, tiger

Human beings are considered omnivores as they can eat plants and meat.

c. **Decomposers** are insects and microorganisms like fungi, bacteria, and virus, which live by eating organic matter such as fallen leaves, dead body and dung animals. They are scavenger insects sometimes called neutrals.

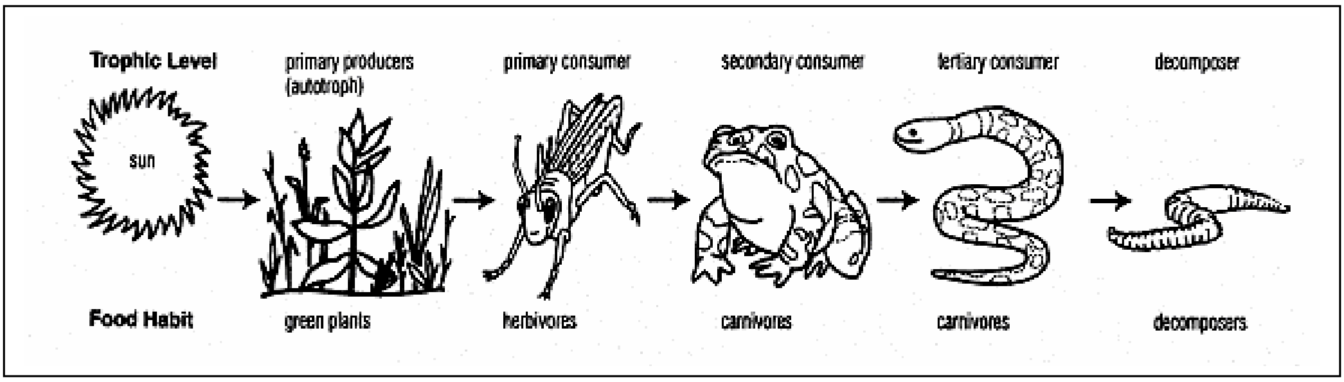
B. The Relationship of the Components of the Ecosystem

Organisms are interrelated with plants and animals. One important relationship between plants and animals is the concept of **food chain**.

Plant receives energy from the sun and converts it to chemical energy through the process of photosynthesis. Similarly, plants get food from the soil. In both cases of energy transfer, from the sun and the soil to the plant, some energy lost as heat cannot be used to make the living matter of the plant. This is also true when animals eat plants. Typically only about 10% of the energy is effectively transferred at each link of the food chain. This process can be represented by what is known as the **food pyramid**.

All organisms that share the same general types of food chain are said to be at the same **trophic level**. Thus, green plants (producers) occupy the first trophic level, carnivores (secondary consumers), which eat the herbivores, occupy the third trophic level, and the top or secondary carnivores (tertiary consumers) that eat each other, and other carnivores occupy the fourth trophic level. The classification of species into trophic levels is based on the function, rather than the species itself. Humans are considered to be omnivores, for they eat plants and animals.

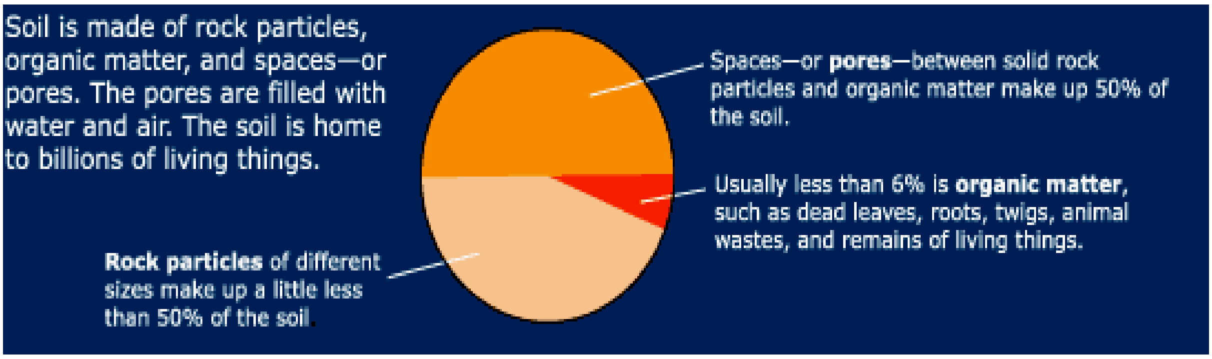
There are many food chains in the ecosystem that are interconnected with one another because the organisms themselves are interrelated with one another. The complex series of many interconnected food chains is called a **food web**. Food webs are an important factor in understanding the importance of maintaining plant and animal diversity. When plant and animal species are lost, breaks can occur in the food chain and food web.

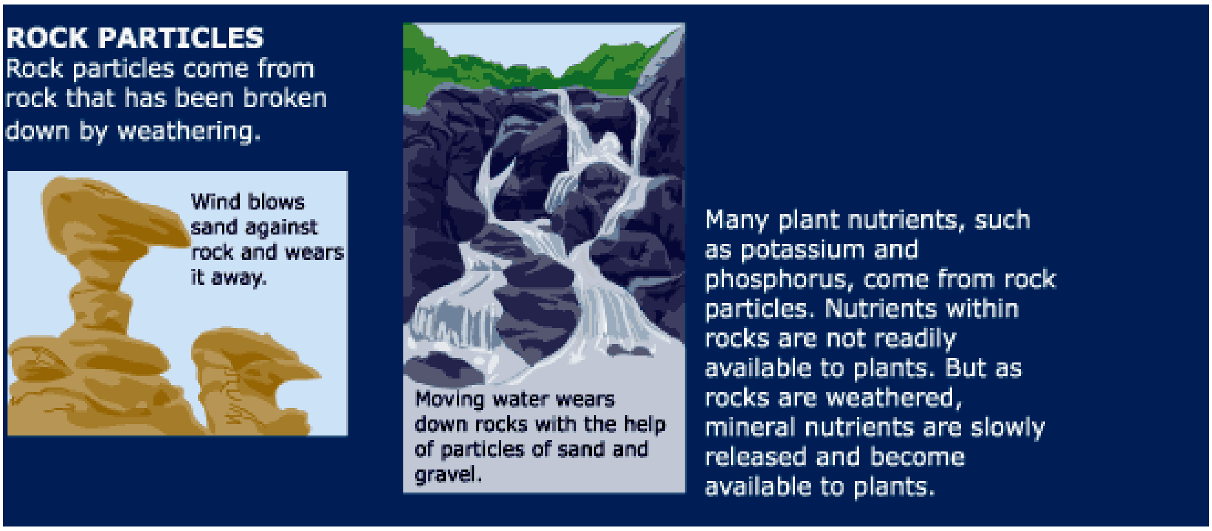


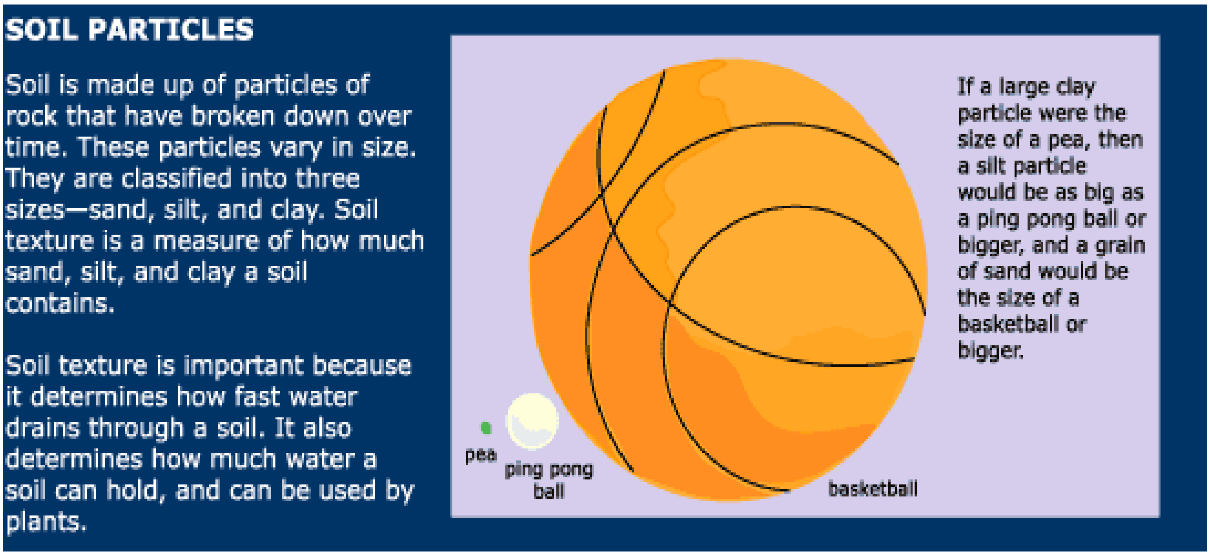
Links of Food Chain (www.knowledgebank.irri.org/IPM/appecology/PrintDoc/AppEcology.doc)

PART III. THE LIVING SOIL

A. Soil Defined







B. Soil Texture

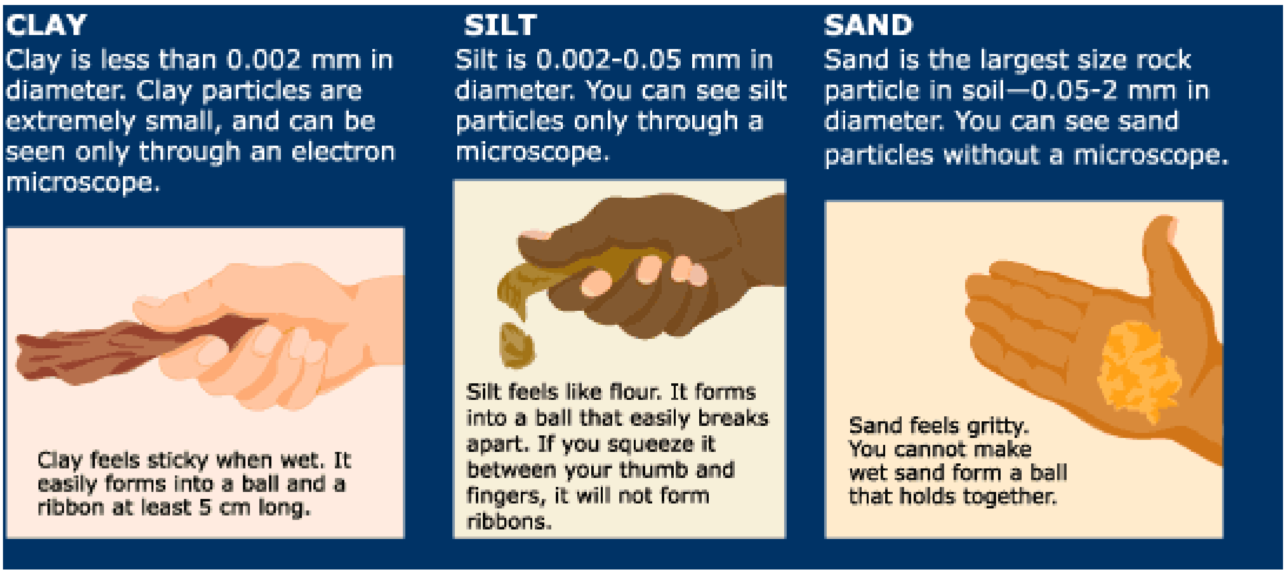
Soil Texture, as has been defined by soil scientists to facilitate the discussion of soils, refers strictly speaking to the ***proportion of sand, silt and clay particles that comprise a particular soil sample.***

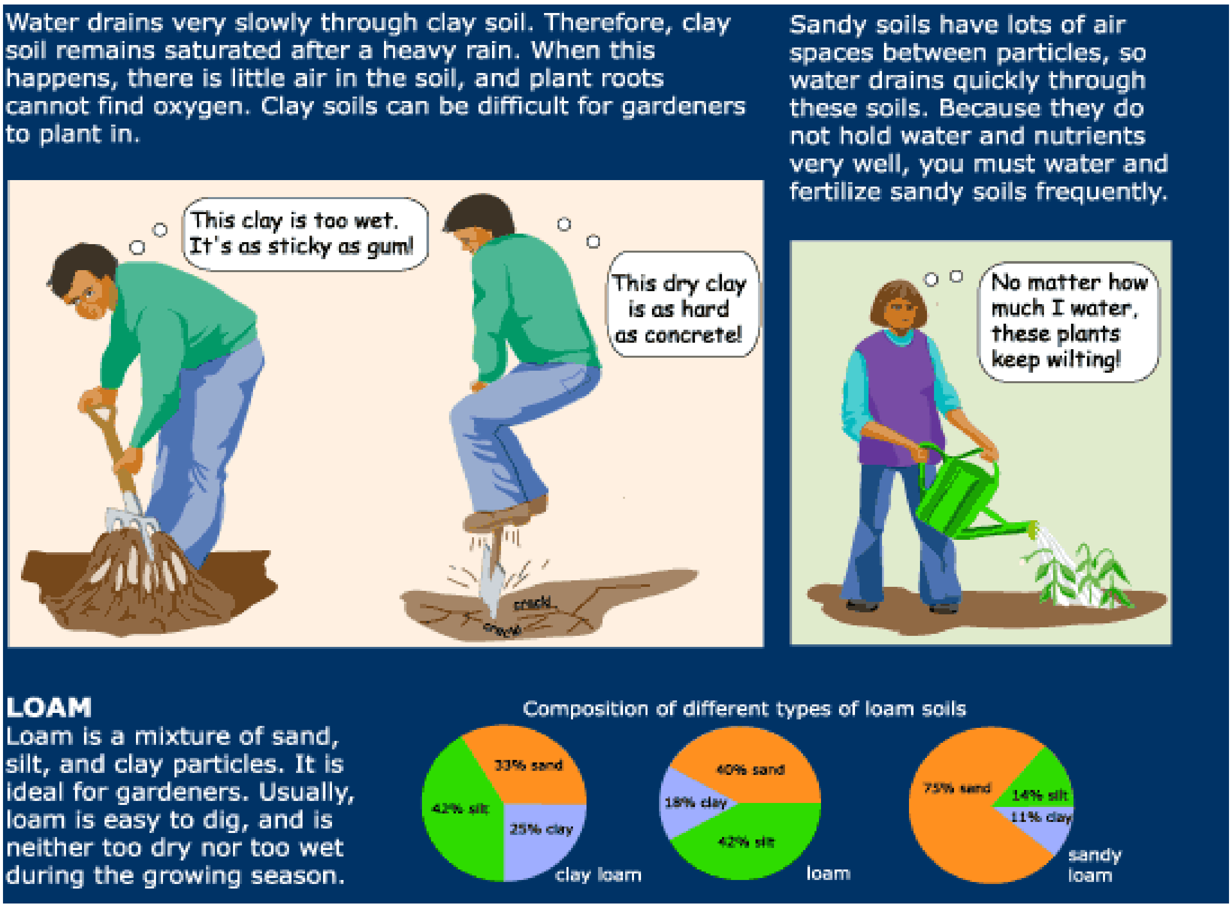
- **Sand** is a type of soil with particles having diameters ranging from 0.05 to 2.0 millimeters.
- **Silt** is a type of soil with particles having diameters ranging from 0.002 to 0.05 millimeters.
- **Clay** has particles with diameters that are less than 0.002 millimeters.

Soils may also be described as ***coarse*** or ***fine.*** A coarse-textured soil has more sand, whereas a fine-textured soil has more clay. A soil with properties equally influenced by sand, silt, and clay is called a ***loam*** or loamy soil.

Soil texture is not something that can be changed in a short span of time. It is essentially what a particular learner is "given" to work with. In the long-term, texture might be changed by events, such as flooding or landslides where large deposits of soil from another region are deposited in the soil of another region. It should be noted that the addition of organic matter does not change the soil texture. However, it does change the other characteristics of soil, such as structure, water-holding capacity, drainage, and nutrient-holding capacity – in fact, almost every important characteristic except texture. Since this idea can be confusing for many learners, this concept must be explained with utmost care.

The texture of a soil is directly related to many important aspects of fertility. For instance, the ability of a soil to absorb and retain water, and to hold plant nutrients directly affects the ability of roots to develop and move through the soil. Soils with a lot of clay are said to be "heavy" soils and tend to hold a lot of water, which makes the water move slowly. Soils with a lot of sand are considered "light" soils because they tend to hold very little water, unless they also contain a lot of organic matter. Water infiltration (movement) in sandy soils tends to be very rapid.





C. The Soil Triangle

Figure 1 shows a textural triangle. The bottom of the triangle is labelled sand, the left side silt, and the right side clay. Each side is divided into 100 segments. If people know the percentage of sand, silt, and clay in the soil, they can easily determine soil texture. For example, if a soil is 40% sand, 30% silt, and 30% clay, the texture is clay loam.

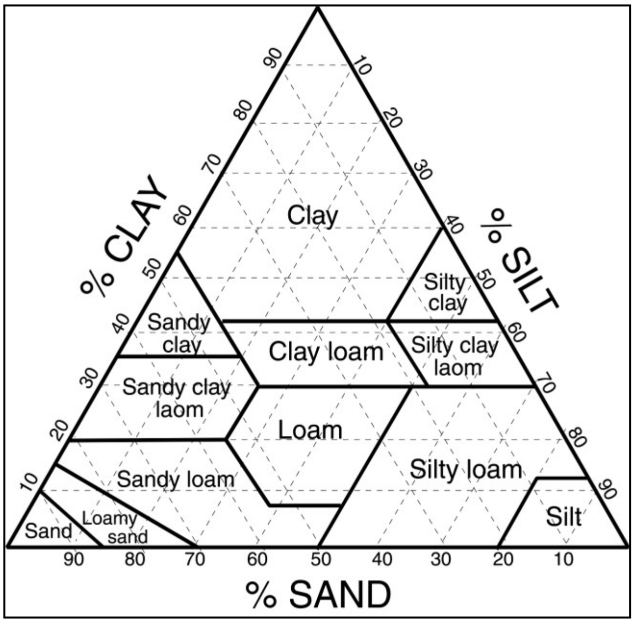


Figure 1The Soil Triangle

Note: To determine the texture, lines from the sides must be extended in the correct direction. The triangle is equilateral i.e., all angles are 60 degrees. Proceed as follows:

Clay extend line horizontal from the % clay i.e., parallel with side labelled sand

Silt extend line downward from % silt at 60 degrees i.e., parallel with side labelled clay

Sand extend line upward from % sand at 120 degrees i.e., parallel with side labelled silt

D. Soil Structure

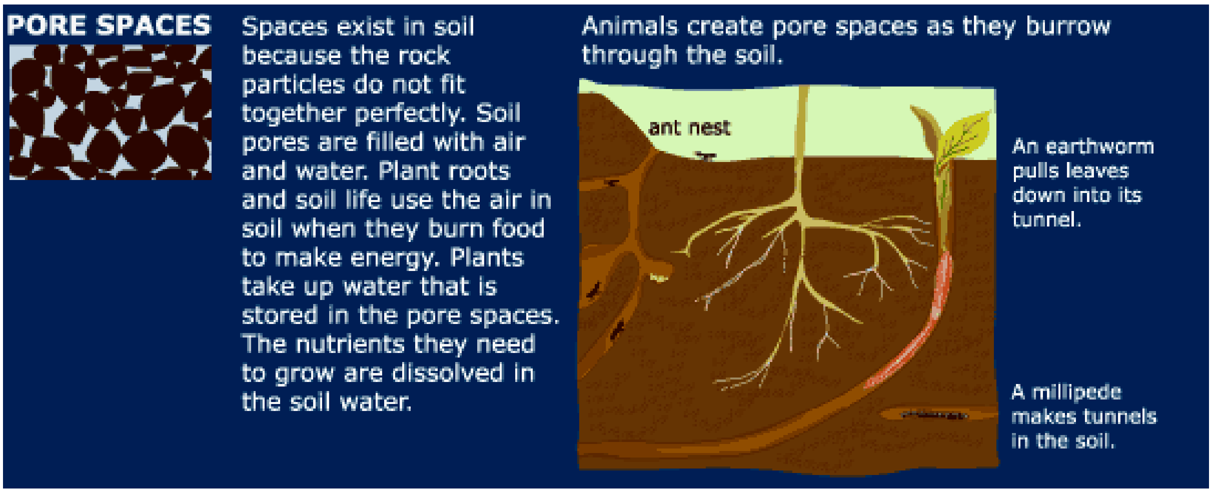
Soil Structure refers to the geometry or physical arrangement of the soil particles in relation to each other. Unlike texture, soil structure can be modified by the farmer through activities such as tillage and water management. Other factors also affect soil structure, such as the action of insects, worms and microbes.

A poor soil structure may result in the need for greater amount of nutrients and a greater amount of water to produce the same level of plant health that a good soil does.

E. The Soil Profile

Soil characteristics, such as texture and structure can be examined from small samples taken from the field. However, it should be recognized that in such cases, soil profile is being considered independently from the actual field conditions. In the field, the behavior of soil systems depends on characteristics of soils at several levels or depths. The analysis of a soil profile is an examination of the vertical distribution of soils. Classification of such systems takes up much of typical soil science texts, and tends to be highly complex in nature.

In its simplest form, we can consider two layers of soil: topsoil and subsoil. The topsoil character can differ dramatically from what is found in the subsoil. Therefore it is difficult to predict what a soil profile might be by simply examining the topsoil.



F. Drainage

Fresh rainwater carries dissolved oxygen needed by the soil, as well as nutrients needed by the plant. So the soil must be **porous** enough to permit good drainage and to prevent the water from standing and becoming stale. If drainage is too rapid, however, the soil will lose both the plant nutrients (which are subject to **leaching**) and water. If the drainage is too slow, nutrients will be depleted in the areas surrounding the roots, and they will not be replenished at a rate adequate to the needs of the plant. Slow drainage may also cause toxicity problems related to anaerobic conditions (lack of oxygen), leading to build-up of intermediate breakdown of products such as alcohols and acids that are toxic to the roots. Poor drainage (too fast or too slow) is a major cause of poor plant growth, but is oftentimes rarely recognized by many farmers.

Drainage at a particular location integrates several factors; clearly drainage is related to both the structure and texture of a soil. Furthermore, the drainage at a particular location is related to the soil profile.

Ideal drainage may be achieved in a soil which contains open spaces of various sizes; wide spaces permit drainage, and small spaces trap water and allow for capillary movement of water.

Plants are continually growing roots into the soil to establish new sites of contact between root and soil. Most roots have a system of smaller and smaller branches, all the way down to microscopic "rootlets". However, ***the amount of root material in direct contact with the soil is still very small***. The plant, therefore, depends on the soil's ability to move enough water through the soil, in order to bathe the roots in water, food and oxygen.

Soil aggregates are particles of soil material—minerals and organic matter—bound together. Aggregation occurs in two phases: formation and stabilization. The aggregates are formed by alternating cycles of hot and cold, or wet and dry. These alternating cycles cause the particles to clump together (forming the aggregate), but unless the aggregates are "stabilized", they will quickly dissolve in the soil water. The clumps may be stabilized directly by the action of soil organisms (for example fungi, which physically surround the aggregate) or by cementing agents created from decaying organic matter, bacterial action, or even by soil passing through the gut of worms.

G. Organisms in the Soil System

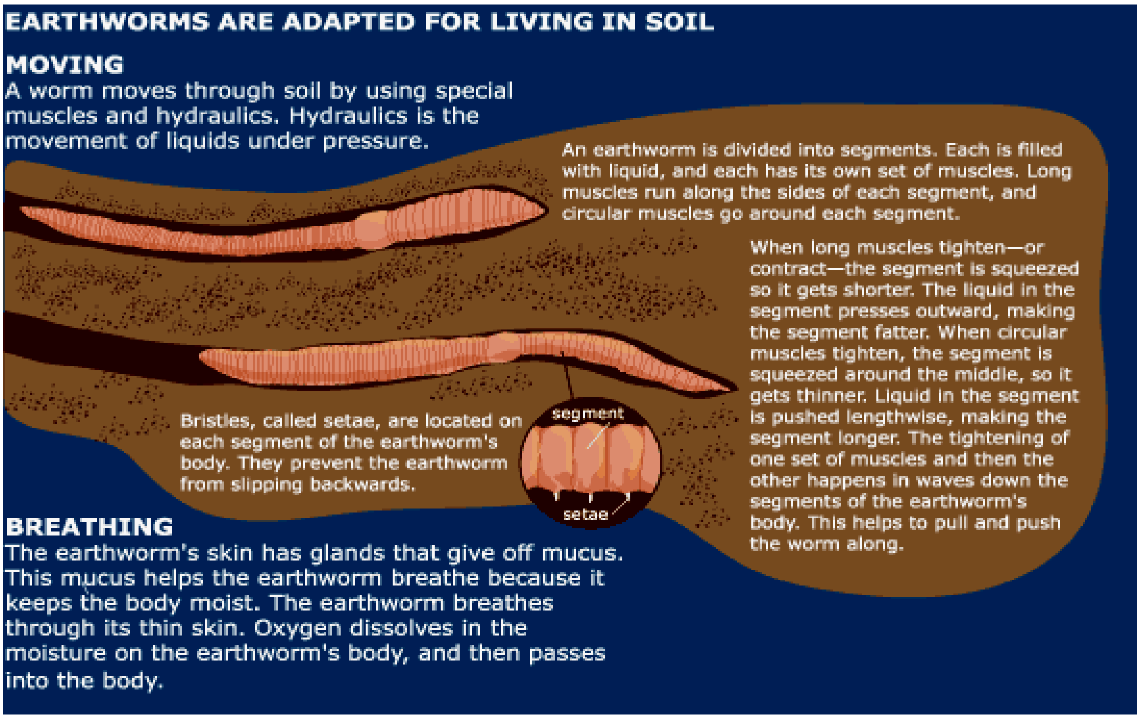
"Feed the Soil and Let the Soil Feed the Plant"

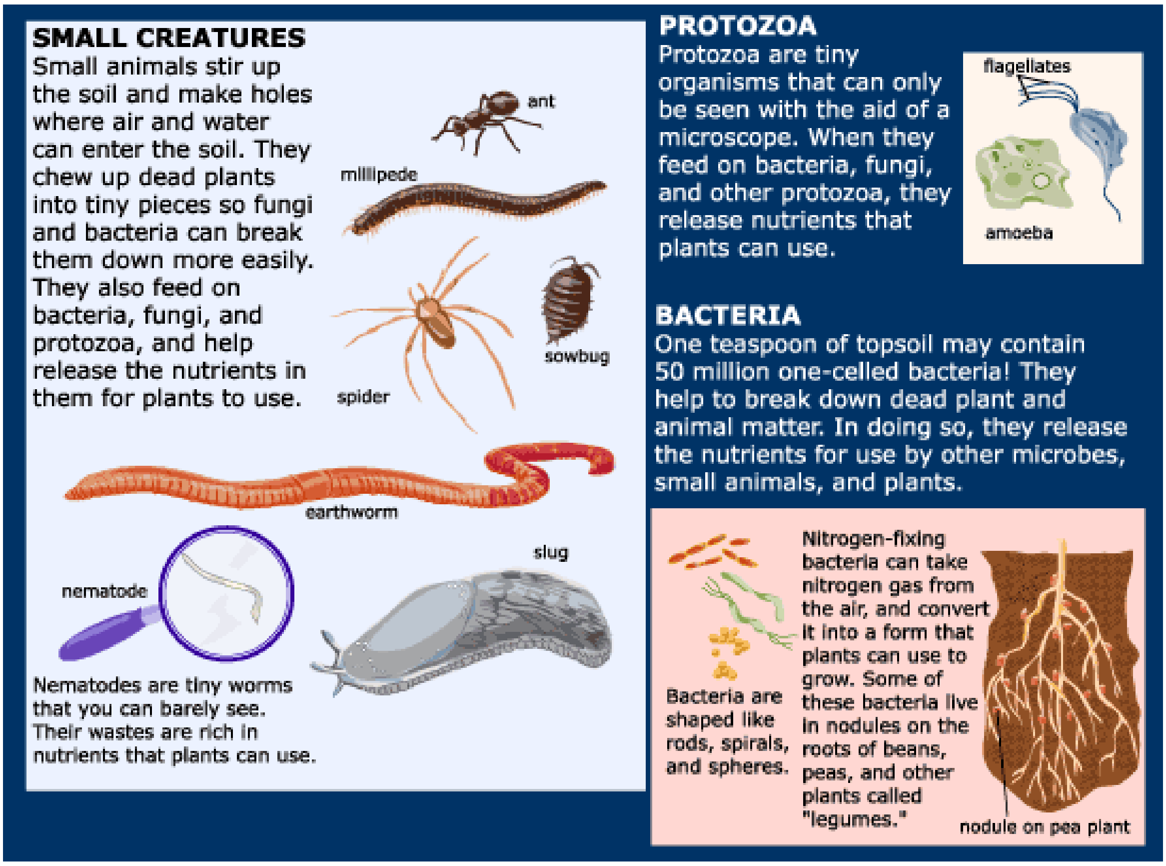
1. Soil Microorganisms: Farmers' "Friends"

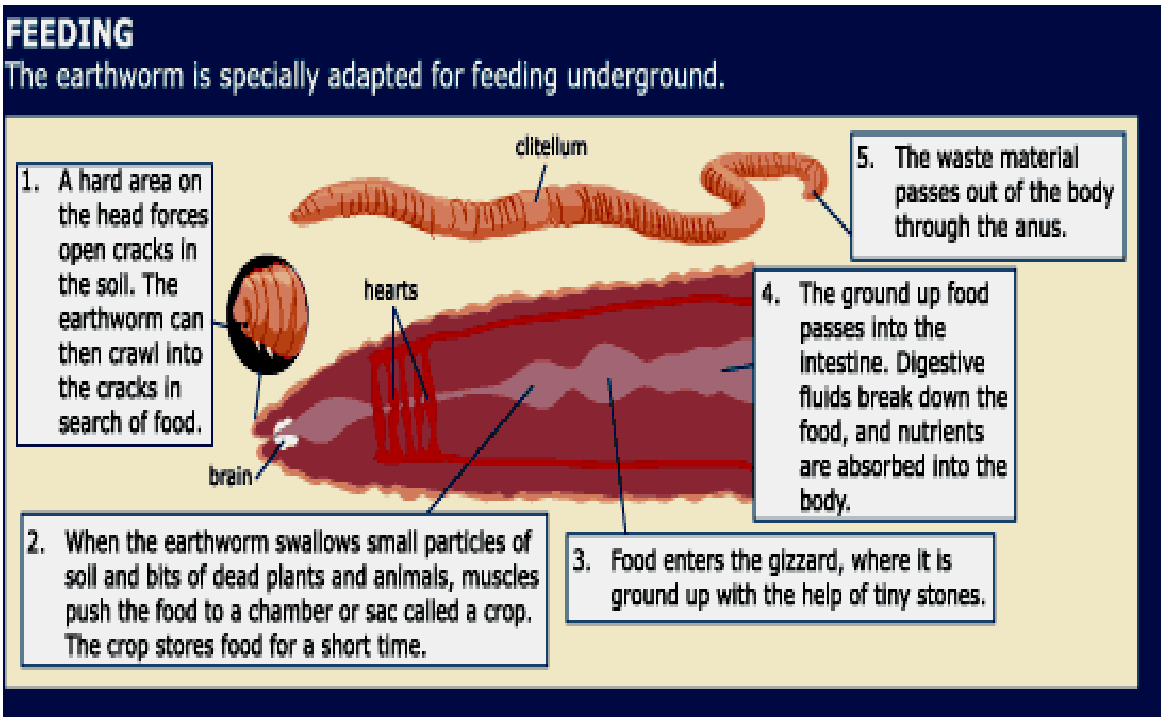
The majority of soil-living organisms are bacteria, fungi and nematodes. While some of these organisms cause diseases to crops, majority of these organisms actually serve a positive role. Many of the fungi serve to breakdown and process dead organic Matter (OM) into smaller-and-smaller components. These organisms are called **saprophytes**. Many of the bacteria serve a useful function in transforming nutrients into forms that are easily absorbed by the plant roots. Still others - both fungi and bacteria - may act as predators and parasites that help protect the plant roots from being attacked by diseases and pests. Thus, just like in the above-ground system, there exist "friendly" organisms that can help farmers fight pests and natural enemies in the soil system.

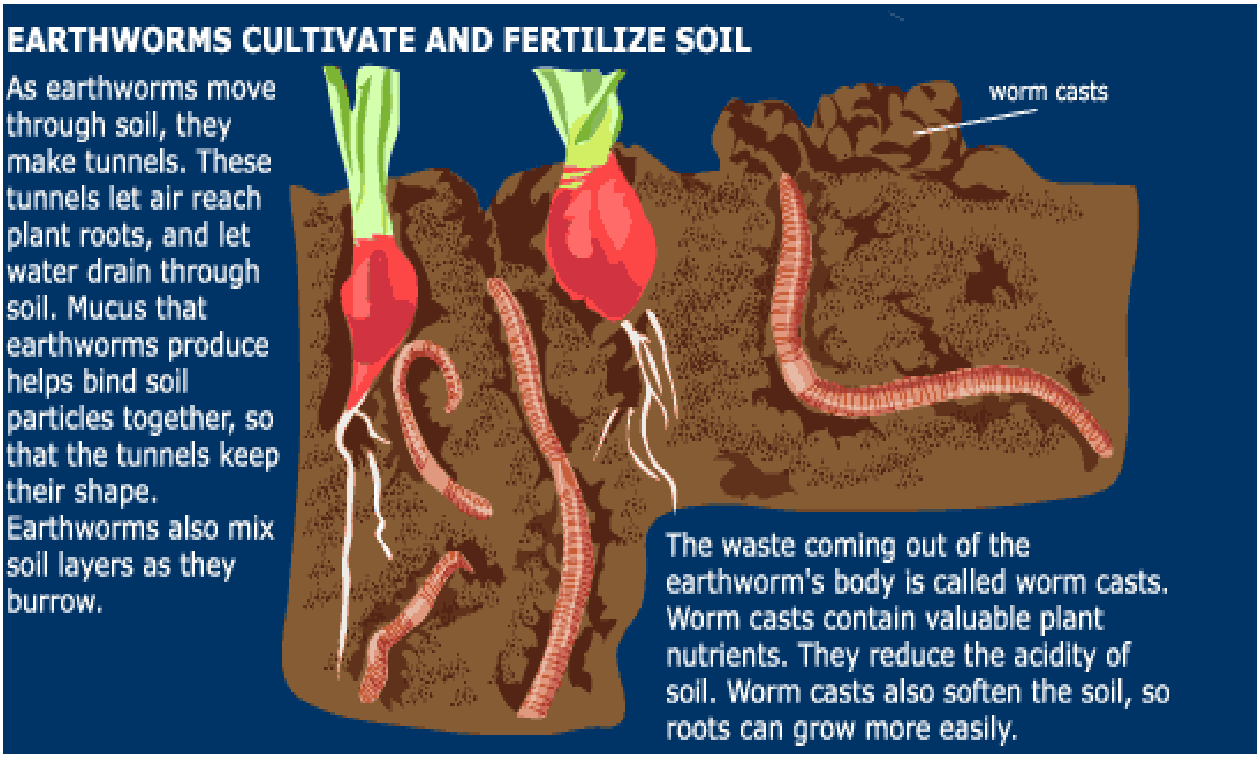
Plant roots also encourage soil aggregation. Roots pushing through the soil, together with dead roots, which cause cementing, help to form soil aggregates. Grasses and grains are particularly effective in promoting good soil structure, owing to the extensive network of their root system.

2. Earthworms: Their Role in the Living Soil









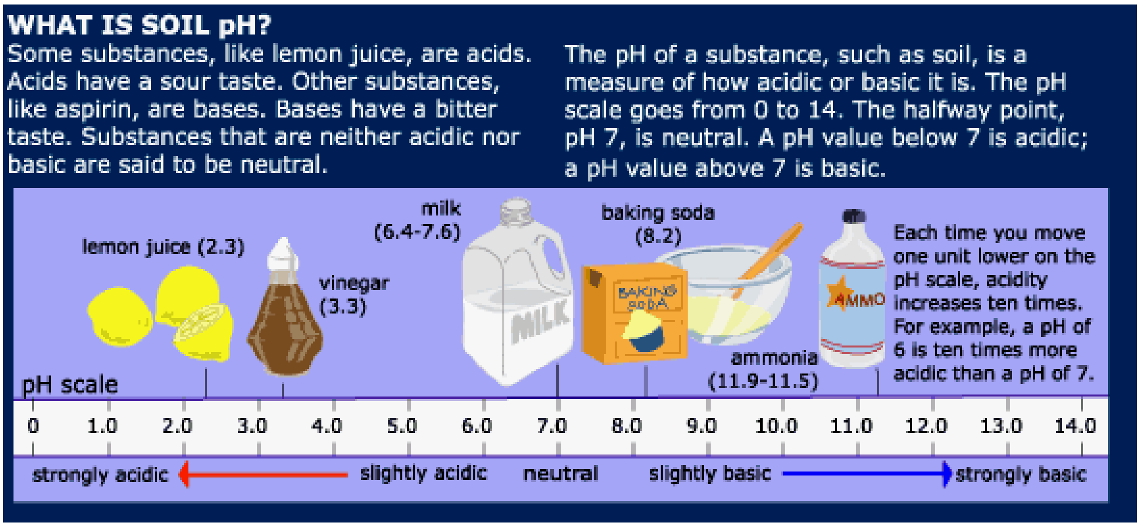
Three practices are necessary to ensure a good soil structure:

- Keep some kind of crop growing as much as possible throughout the year, to encourage maximum root growth;
- Recycle crop residues to replace carbohydrates lost through biological activity; and

- Minimize disturbance of the soil, which would reduce biological diversity and accelerate the destruction of soil structure and organic matter.

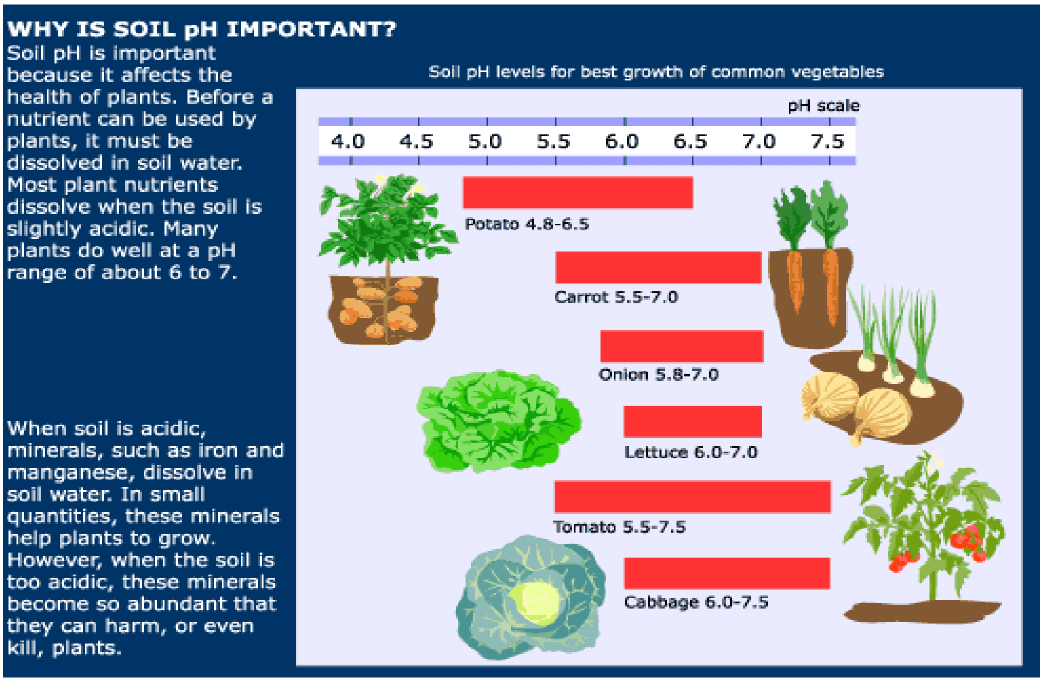
H. What is Soil pH?

The **pH** of a soil refers literally to the **Potential Hydrogen** and is a measure of the soil acidity. Technically, pH refers to the amount of hydrogen ion (H+) present in the soil water (or any kind of liquid), measured on a logarithmic mathematical scale. In rice production, knowledge of soil pH, particularly how to measure and manage it, is very important especially since pH affects soil chemistry and plant nutrition.



The pH is a scale of measuring acidity that ranges from 0 to 14. A low pH (0-5) is **acidic**, and a high pH (9-14) is **basic** (lacking H+). A pH level that ranges from 6 to 8 is considered **neutral pH**.

In many areas of the tropics soils are generally acidic. Some soils have a pH level of as low as 4.0 and some even have as low as 3.0 pH. Soil acidity does not directly hurt the plants, but rather, it affects the availability of nutrients for the plant. The same is also true for soils that are too basic (lacking in H+).



To further explain the idea of soil pH, a more general analogy can be used. Imagine the soil as a huge pantry or a place for storing food in the house. The pantry must be a good-enough cabinet, cool enough to maintain the freshness of the food kept in it. Similarly, the soil has to have the good qualities for it to be an appropriate storage place for nutrients. In the case of sandy soil or a soil under high rainfall conditions, the nutrients are often leached or dissolved. Thus, the "pantry" turns out to be a poor place for storing food. In this case, putting OM back into the soil is just like stocking the "pantry" with food. An ideal soil with a good mixture of sand, silt, clay and organic matter, therefore, is like a large pantry that allows storage for many kinds of food. If the soil pH is too low or too high, storage of nutrients will be difficult and the "pantry" will be empty. Thus, to increase soil nutrients, pH level must be maintained at a desirable balance.

Improving Acid Soils

Lime is the most common material used to neutralize acid soils. Lime in pure form is calcium carbonate ($CaCO_3$). What is important in lime is not the calcium (Ca^{++}), although calcium is a required nutrient for plant growth. Rather, it is the carbonate (CO_3^{-}) that helps balance the pH level of acid soils. It does this by combining with the hydrogen ion (H^+). Each carbonate molecule combines with two hydrogen ions, and in this way the lime "cleans up" the excess H^+ and raises the soil pH toward neutral.

The formal description of the reaction goes as follows:

$$2\,CaCO_3 + 3H^+ \longleftrightarrow 2Ca^{++} + HCO_3^- + H_2CO_3$$

For every two molecules of $CaCO_3$, 3 ions of hydrogen ($3H^+$) are taken up (lowering the pH), producing $2Ca^{++}$ (which are now available for storage in the soil, or uptake by the plant), and one molecule each of bicarbonate (H_2CO_3) and HCO_3^-.

The amount of lime needed to raise soil pH to a neutral status depends on the type of soil and on the initial pH. Table 1 presents a rough guide to raising soil pH.

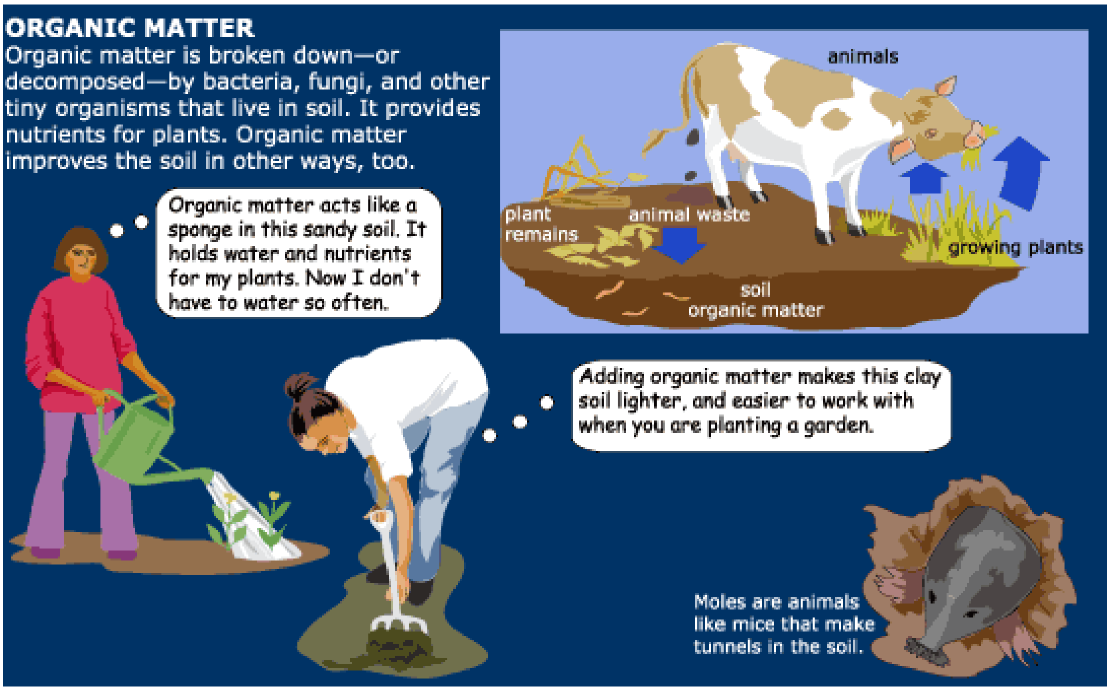
Table 4. Lime Requirement for Specific pH

pH	Lime T/ha
4.0	10.24
4.1	9.76
4.2	9.28
4.3	8.82
4.4	8.34
4.5	7.87
4.6	7.39
4.7	6.91
4.8	6.45
4.9	5.98
5.0	5.49
5.1	5.02
5.2	4.54
5.3	4.08
5.4	3.60
5.5	3.12
5.6	2.65
5.7	2.17
5.8	1.69
5.9	1.23
6.0	0.75

I. Role of Soil Organic Matter

1. Soil Organic Matter (SOM)

When the nutrients, enter the living organisms, they tend to circulate, moving through a food web where they are eaten by other organisms. For example, nutrients initially absorbed by plants might be eaten by a herbivore, which in turn might be eaten by a predator, and so on. At each **trophic level** or feeding level, energy and nutrients can be transferred in only a few ways: a certain fraction of the original plant or animal is passed on to the next trophic level, or returned to the soil – either directly, or in the form of waste products from digestion. Meanwhile, in the case of energy, all organisms respire (breathe) and when this happens, the energy in the form of heat and carbon dioxide (CO2) is lost or goes to the atmosphere. Eventually, every living thing dies and goes back to the soil unless the nutrients are physically removed from the system just like what happens with products after harvest. What happens in this process is important for farmers because the **soil organic matter (SOM)** plays critical role in the functioning of the ecosystem, and in the health of the soil and crops.



SOM is actually comprised of two parts: the living and the dead. The living parts include the **microorganisms** like bacteria, viruses, and fungi including a great many a host of larger animals like worms, termites, and beetles. Of greatest concern to farmers are the microorganisms (also called **microbes**), for these organisms are responsible for the majority of the processing that takes place when a dead animal or plant enters the soil system.

2. Positive Effects of SOM on Soil Structure

One of the most important benefits of SOM is the effect it has on soil structure. ***SOM has a very significant positive effect on soil structure***. It provides the raw materials for the "cements", which bind and stabilize soil aggregates. It also stimulates the growth of microorganisms and soil animals that contribute to aggregate stability. Residues high in carbohydrates are best in promoting stable aggregates. For example, straw is considered to be more effective than cow dung because it has more carbohydrates.

3. SOM Acts as a "Buffer"

Many farmers may think that they "feed their plants" by adding inorganic fertilizers (Nitrogen, Phosphorus and Potassium or NPK) to their soils. In fact, as long as there is good SOM in the soil, inorganic fertilizers do not go to the plant directly. Rather, 80-90% of the inorganic fertilizers are absorbed into the life cycles of the **soil microbes** as these microbes grow and multiply. Only when the microbes die are the nutrients from their decomposing bodies broken down into small molecules and freed into the soil to be absorbed by the plant roots.

In exactly the same process, most of the nutrients from the breakdown of SOM itself will be taken up by growing populations of microbes. Thus, soil microbes first absorb all nutrients, whether organic or inorganic, before these nutrients become available to the plant. Thus, SOM acts as a buffer or something that protects the plants from damage.

In this way SOM, together with the microbes that feed on it, will bind or capture nutrients in a form that allows the stable long-term storage of nutrients, and their slow release into the soil and eventually into the roots of the plant. This is a much more efficient way to feed the plant because nutrients are released **slowly** over a longer period of time.

In contrast, soils with little or no SOM also have poor populations of microbes. As a direct result, the nutrients and microbes that process the other nutrients are not available. Therefore, if farmers add inorganic fertilizers to their soils, the nutrients will float around in an "unbound" or free form. Some nutrients will be absorbed directly by the plant roots, but the large majority will be lost to leaching by rainwater or irrigation water. In the case of Nitrogen, **volatilization** and **denitrification** back into the atmosphere happen. In addition, the plant may be "flushed" with nutrients very quickly. Too much fertilizer, entering the plant too quickly, can cause problems with disease and with lodging.

4. SOM and Microbe Growth

Plants take their carbon directly from the atmosphere, but are dependent on Nitrogen and other nutrients that are processed by microbes in the soil ecosystem. Microbes also need carbon for energy and Nitrogen for building proteins (although a certain group of microbes can "fix" nitrogen directly from the atmosphere). Unlike plants, however, microbes cannot get their carbon directly from the atmosphere. Instead, they are dependent on plant residues for their source of energy in the form of carbon compounds.

This is why returning plant residues to the soil is critical for maintaining the health of a soil and the productivity of a farming system: ***putting residues back into the soil feeds the soil microbes, which in turn, feed the plant***.

5. Carbon and Nitrogen Ratio (C:N)

One of the most important characteristics of Organic Matter (OM) is the amount of carbon compared with the amount of nitrogen (or the ratio of carbon to nitrogen, written as C:N). As was discussed, microbes need carbon for energy and nitrogen for growth and development. The bodies of bacteria have a certain ratio of C:N, usually about 8:1. However, different kinds of organic matter have different ratios of C:N. Almost always OM is much higher in carbon than in nitrogen. Rice straw, for example, has a C:N ratio of about 200:1. When a large amount of OM with a high C:N ratio, is added to the soil, microbes initially grow quickly in the presence of a new energy (carbon) source. However, as the nitrogen in the OM is used up, the microbes draw upon the nitrogen available in the surrounding soils. This brings them into a competitive relationship for any plants that might also be in the same soil. This can cause nitrogen deficiency in the developing crop if low-nitrogen SOM is added to the soil just before planting the crop. Therefore farmers must be careful in adding "unprocessed" plant residues.

This problem can be avoided in several ways:

- Incorporate the straw into the soil several weeks before planting the crop.
- Add nitrogen, in the form of urea, to the soil together with the straw.
- Compost the straw first for several months before adding it back into the field (compost has almost the perfect balance of C:N for soil microbes).

6. Anaerobic Decomposition and Poor Drainage

Anaerobic condition or lack of oxygen happens in about two hours after the flooding of the field. This occurs because oxygen movement is 10,000 times slower in the water than in air. When the oxygen supply from the air cannot meet the oxygen demand of aerobic (or oxygen-breathing) organisms in the soil, anaerobic conditions develop.

Flooding a field causes the death of many organisms, and therefore the release of nutrients locked up in their bodies.

In an anaerobic environment, ammonia and ammonium (NH_3 and NH_4+) are stable products of nitrogen metabolism in bacteria. However, nitrate (NO_3) is rapidly denitrified and lost back into the atmosphere as Nitrogen gas.

Low yields in China have been attributed to poor drainage. For heavy clayey paddy soils, which are derived chiefly from alluvial and lacustrine deposits (like the Jalur Pantura in northwestern Java), poor yields are attributed to generally small pore spaces, which are poor in aeration and permeability, although good in water retention ability.

To improve soils with poor drainage, to promote their fertility, and ultimately increase rice yields, it is essential to provide proper drainage, thereby improving aeration in the root layer. Drainage is not only effective in improving soil characteristics, but also a practical technique for substantially increasing rice yields – as proven by many experiments in China and elsewhere.

Drainage conditions also inevitably affect the decomposition and accumulation of organic matter. There is always a greater accumulation of organic matter in poorly drained paddy soils simply because it does not break down as rapidly (fewer microbes). Under good water regime, SOM plays an active part in the improvement of physical properties of paddy soil. On the other hand, with a poor water regime (poor drainage), it is difficult to improve soil physical properties and increase soil fertility by raising the content of SOM.

J. Principal Nutrients

1. Nitrogen

Nitrogen (N) is an essential nutrient for all living plants and animals, and in a manner of speaking; N represents the "action" of life. N controls the movement of energy and materials and the growth of the plant by its large contribution to every complex protein (e.g., chlorophyll, enzymes, hormones).

The atmosphere is the major reservoir of N. Roughly 80% of the air is nitrogen gas (two atoms of N, or N_2), but neither animals nor plants directly breathe N2 from the air. The reservoir of nitrogen is only very slowly **cycled** into the soils and water via the action of microorganisms that **"fix"** nitrogen from the atmosphere into the bodies of the microorganisms themselves. These microorganisms live mostly in the soil, but some live inside plants.

The cycle starts when nitrogen is **"fixed"**, and taken into the bodies of certain types of bacteria, which directly use them to grow more bacteria. When these bacteria die, (bacteria do not live a very long time), the nitrogen, in the form of **proteins** and **organic molecules,** along with other nutrients in their bodies are then broken down by the action of other **saprophytic** (decomposer) bacteria and fungi. These saprophytes in turn, use these nutrients in their own growth, and also release part of the nitrogen into the soil in forms that can be taken in by plant roots and by other microbes. The decaying process of dead organic matter, which releases nutrients to the surrounding soil, is called **mineralization**. On the other hand, the process of nutrients again being taken in and incorporated into the bodies of living microbes is termed **immobilization.**

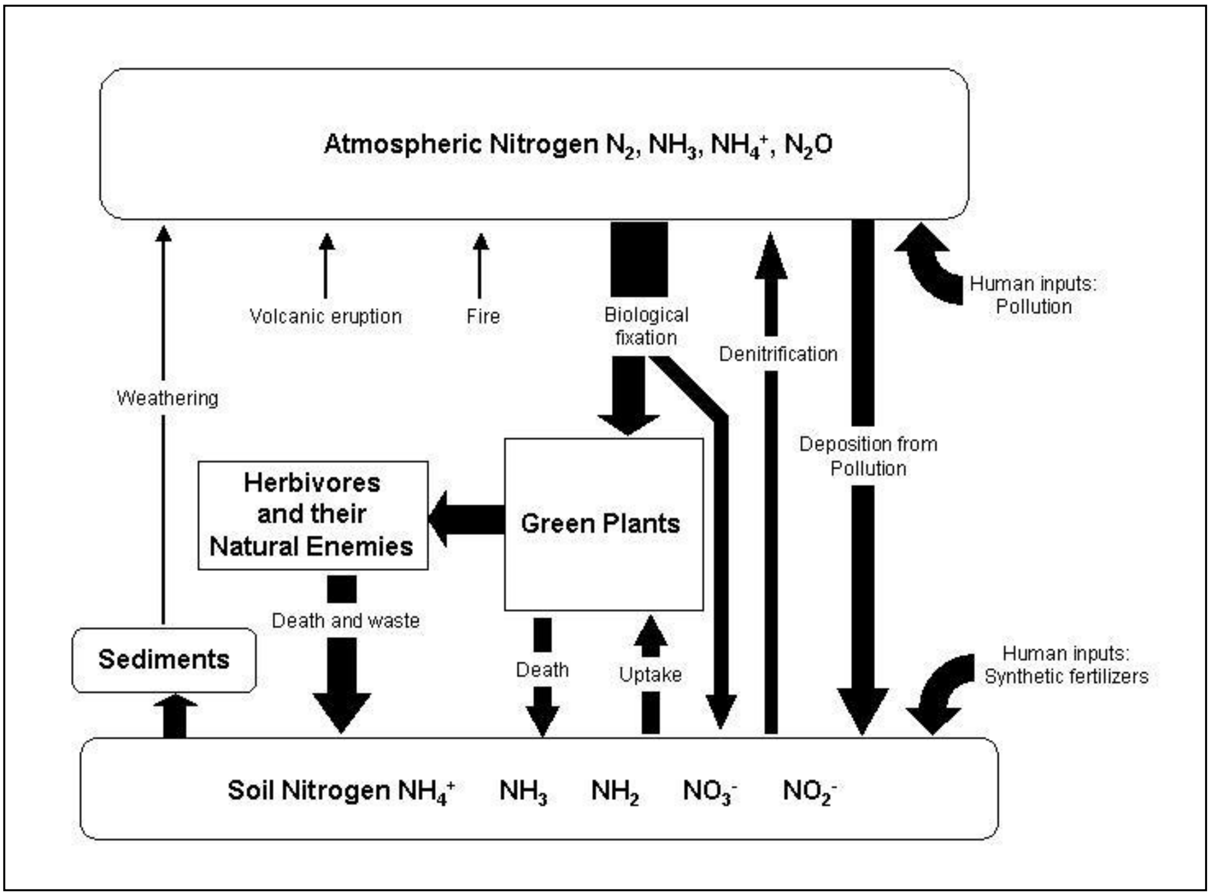
The principal pathway for N2 to enter living organisms from the air is via certain types of bacteria. Many of these bacteria live in soils. Others, like **Cyanobacteria**, live in aquatic systems like rice paddies and inside the cells of specific kinds of algae for example, the blue-green algae. Cyanobacteria in a rice paddy may fix up to 100-150 kilograms of N per hectare per year. Other bacteria, such as those of the genus **Rhizobium**, live inside the roots of leguminous plants, and still others live inside the leaf cells of plants, like Sesbania. Both Cyanobacteria and Rhizobia are so successful at fixing large amounts of nitrogen because each has access to large sources of energy. The Cyanobacteria live inside algae, so they are closely associated with algae. Through photosynthesis, the algae are able to offer carbohydrates (C) to bacteria, and in return, the bacteria fix nitrogen, some of which benefits the plant. In a similar manner the Rhizobium bacteria are associated with the roots of plants, receive food (carbon) from the plant roots, and "pay back" its host with nitrogen.

The limited paths in which nitrogen finds its way into living systems explain why nitrogen, of all the soil nutrients, would most likely be lacking in soil. Yet all life requires N in large amounts; as a result, natural supplies of N are almost always limited and most plants become very good at competing for N supply.

a. The N Cycle

One of the mysteries of life is that although nitrogen is needed by all living things in fairly large amounts, and although our atmosphere is a huge reservoir of nitrogen, the paths by which nitrogen can enter ecosystems are very limited - the doorway opens through a few species of bacteria. As a result, nitrogen tends to be a limiting nutrient in the growth and development of many organisms, most especially plants. A limiting nutrient is the one (and by definition, there is only one at a time) nutrient that is in greatest demand and whose absence slows the entire process of growth.

Nitrogen can take several forms in the soil, depending on how it combines with other atoms. In addition to the many forms in which nitrogen is found in living things, nitrogen can be found in inorganic forms in the form of nitrogen salts: ammonium [NH_4+], nitrite [NO_2-], and nitrate [NO_3-]. Like any salt, all three forms of Nitrogen salts are highly water-soluble and as a result can be found most anywhere on the surface of the planet. The nitrogen salts are very actively cycled and recycled back and forth between inorganic forms and organic forms. The two main forms accessible to plant roots, and therefore the forms highlighted here are NH_4+, and NO_3-.



Synthetic nitrogen is applied at a rate of about 40 million tons per year, worldwide. **Deposition** (entry into the soils) of nitrogen from pollution is roughly 100 million tons per year. This is mostly in the form of nitrous oxide (N_2O, one of the greenhouse gases) and NH_4^+ in **dry deposition**, and in the form of nitrate (NO_3^-) and ammonia (NH_3) in **wet deposition** (rainfall). Nitrogen input to soils from pollution can be as much as 40 kilograms per hectare per year. Biofixation of N accounts for roughly 140 million tons per year worldwide.

b. Too Little N

If nitrogen in the soil is low, almost all plant functions are disturbed and the most direct result is that plant growth is stunted and plant color turns pale green to yellow. Four N atoms surround a single magnesium atom to form the core of the chlorophyll molecule; hence, limited N reduces the photosynthetic capacity of the plant. Nitrogen is highly mobile in plants, so when N is low it drifts from older leaves to newer leaves and the older leaves will turn light green, yellow or even pink. This is one good indicator of nitrogen deficiency, although people must be careful not to get this confused with one of several diseases or even soil drainage problems.

c. Too Much N

Too much nitrogen can be poisonous to a plant. If too much nitrogen is present, the plant diverts energy, carbohydrates, water and minerals in an attempt to digest and get rid of the excess nitrogen. As a result, ***nitrogen causes an imbalance in the plant's health***. Too much nitrogen causes the following problems:

- Plants become overly succulent.
- Tubers become watery and eventually rot.
- Rice plants become too tall and weak and they "lodge" (fall over).
- Flowering and fruiting may be delayed.
- Fruits ripen unevenly.
- Vitamins A and C content in fruits drop.
- Problems with diseases and insect pests increase. For example, sheath blight and many kinds of sucking insects pester plants having very high levels of nitrogen.
- Leafy vegetables like lettuce build-up toxic nitrates in the leaves. Nitrates and nitrites have been shown to cause cancer in animals. Exports of leafy vegetables from some countries are banned after laboratory analysis shows nitrate content to be beyond a certain safe limit.

d. "Inorganic" Nitrogen: Urea

Urea is considered an "inorganic" or artificial form of nitrogen although its origins are from natural, organic substances. Urea comes from **natural gas,** which is taken out of the ground in much the same way that people drill for oil. The fact that natural gas takes millions of years to be created means that once we use up the natural gas found in the soil, it could not be replaced anymore. For this reason, natural gas like urea is considered a **"non-renewable"** resource. Urea is created from organic substances that had been trapped in soil sediments under anaerobic conditions and millions of years ago. Since the organic substances had been trapped, they never had a chance to be decomposed completely.

Urea is made up of two molecules of (NH_2) tied together with a carbon and oxygen atoms (CO), so the molecule is written as $CO[NH_2]2$. When urea is added to soil, water breaks it down into two molecules of ammonia (NH_3), and carbon dioxide (CO_2) is released in the process. For urea to be decomposed into ammonia, the action of microorganisms is required.

Several studies have been done through the years using "labeled" nitrogen, that is, nitrogen with a special mark on the atoms, so researchers can follow exactly where specific nitrogen atoms go. These studies show that when urea is applied to the soil in a rice field, ***under the best of conditions nitrogen atoms end up in the following:***

- 20% end up in the grain
- 12% end up in the straw
- 3% remain in the roots
- 23% are left in the upper 30 cm of the soil, and
- 40% are lost through denitrification and through leaching

e. N Loss from the Soil

1) **Volatilization** of ammonia can take place in the soil when it simply evaporates into the air and is just carried away. This happens after heavy application of manure, and it can occur when urea or ammonia fertilizer is used if the soil pH is high. Recent research, however, has shown that losses can be reduced by adding calcium or potassium salts to the soil.

2) **Leaching** is the washing out of nutrients from soil whenever excess water percolates through the soil, carrying with it any dissolved nitrogen. The best ways to minimize nitrate leaching are to promote biological activity with carbon-rich residues and to maintain a good plant cover, like a green manure. The leaching of dissolved organic materials carries away, not only nitrogen, but also phosphorus, sulfur and trace elements. To minimize leaching, the soil pH should be maintained near neutral. This maximizes biological activity, which aids in the stabilization of soluble organic substances. Also, the calcium in the lime is a good binding agent and reduces the instability and solubility of organic residues.

   Farmers remove nitrogen from the field every time they harvest the crop. A large proportion of the nitrogen in animals and plants is used in the making of proteins. Therefore, in most plants this means that the majority of the nitrogen ends up in the seeds. As a result, when a rice plant is harvested, 70% of the nitrogen in the entire plant is taken away in the form of the harvested grain, leaving only 30% remaining in the roots and straw.

3) **Denitrification** is often the most important cause of nitrogen loss. It is the return of nitrogen to the atmosphere that takes place given three conditions:
   a) Presence of NO_3-
   b) Presence of organic matter that support the bacteria that transform or "denitrify" nitrates back into N_2
   c) anaerobic or low-oxygen conditions (at least in pockets)

   Too much organic matter can encourage denitrification, because such an excess produces enough biological activity to use up all the available oxygen. The amount of OM residues that can cause denitrification depends on the texture of the soil and the coarseness of the organic residues. An open sandy soil can absorb more compacted organic residues than a clayey soil.

   Usually, ***the more one tries to force nitrogen into the soil, the greater the losses of nitrogen from the system***. If a soil is over fertilized with nitrogen, it may find a way to get rid of the nitrogen almost as fast as the farmer puts it on. If the nitrogen is spread in ammonium form, the soil may either cause it to be volatilized or to be rapidly nitrified (converted to nitrate form) and soon afterward lost as a gas by denitrification. If the nitrogen is initially in nitrate form, it may be denitrified, or it may be leached into the groundwater. The leaching of synthetic fertilizers into lakes, rivers and oceans has had a major negative impact due to the stimulation of "algal blooms". The death and decay of these algae as caused by microbes, rob water bodies of large amounts of oxygen, thus causing massive fish kills.

These facts, coupled with the significant cost farmers devote to nitrogen fertilizers, are enough reasons why farmers need to learn how to better manage their nitrogen inputs.

2. Phosphorus

a. Adenosine di-Phosphate (ADP) & Adenosine Tri-Phosphate ATP: The Short-term Storage of Energy

Phosphorus (P) is one of the major nutrients that farmers apply when they buy inorganic fertilizers. It plays several important roles. Notably, it is important in the construction of the genetic material, DNA. Hence, DNA is found in important concentrations in seeds. Also, phosphorus is associated with the short-term storage of energy captured from the sun.

b. ADP & ATP: "Rechargeable Batteries" in the Plant

Phosphorus acts as the **energy transfer agent**. As such, it works by being attached (or unattached) to a small, but very important molecule. The ADP molecule has two phosphates attached (***di*** meaning two) to it, while the ATP molecule has three phosphates. Attaching the third phosphate atom to ADP to make ATP requires (and thereby stores) energy. Similarly, when the ATP molecule has phosphorus molecule "broken off", it gives up energy that can be used by the plant. In other words, ADP is like a battery with the charge gone out, and ATP is like a charged battery.

The energy-charged ATP molecule can and does go everywhere inside the plant, from the smallest root to the tip of the flower, to the inside of the grains. Every cell in the plant uses the ATP molecule to give up energy so that the cell can do its work. In fact, ATP is found, not only in every plant, but also in every animal on earth. It is the "common currency" of energy transfer for all life on earth, from the smallest bacteria to the largest whale or the tallest tree.

c. Behavior in the Soil

The amount of phosphorus found in surface soils ranges from about 200 kg/ha in sandy soils, to about 2,000 kg/ha in soils derived from rocky subsoils. Chemical weathering results in ***solubilization*** of orthophosphate ($H_2PO_4^-$) and pH <7.2 and HPO_4^{2-} at ph >7.2. This is the form in which phosphate is available to the plant, and usually accounts for not more than 1% of the total phosphorus in the soil in any location. This is because the release of orthophosphate (either through solubilization or by application of phosphate fertilizers) is followed by ***precipitation*** (the forming of insoluble solids from chemicals in solution). Phosphorus goes out of solution in the form of iron and aluminum phosphates in acid soils, and calcium phosphates in basic soils. These reactions result in low orthophosphate concentrations at pH levels above or below about pH 6.5.

Another source of phosphorus is from organic matter. Total organic phosphorus accounts for usually between 30—50% of total soil phosphorus, and the ***microbial pool*** (total amount of living and dead microbes) represents the majority of the actively cycling pool of phosphorus.

d. Not Enough P

Seeds contain a large amount of phosphorus, so a deficiency in P might be seen in the small seeds of plants. Phosphorus also stimulates root growth. This can be observed by putting a small source of phosphorus in the soil near the plant roots and then digging down to examine the roots in the area of the phosphorus. The roots in such areas should be longer, stronger and with many fine root hairs.

Unlike nitrogen, phosphorus is not readily absorbed by the roots, so P can be overwhelmed by too much N. P is very rapidly bound by several factors in the soil, so any free phosphorus absorbed by the plant must come from very close by the roots. One problem with P is that it is not very "soluble" (able to be broken into small molecules and to move through the soil and water). Phosphorus is more soluble in a soil that has a good amount of oxygen (aerobic conditions). One benefit from the solubility problem is that it takes a very long time to leach P from the soil. Hence, ***farmers that add phosphorus every season may have built up much more than they need***.

e. Factors Affecting P Movement

The atomic symbol P is used to refer to phosphorus. However, this is just a convention to simplify the text, just like N is used to refer to nitrogen in forms such as nitrate or ammonium. Similarly, P can be found in several forms, both inorganic and organic. The form in which phosphorus is made available to living organisms is most commonly found as ***orthophosphates*** ($H_2PO_4^-$ at pH<7.2 or HPO_4^{2-} at pH>7.2). The pH of a soil affects not only the form, but also the mobility (movement) of orthophosphate. If the soil is near neutral (pH 6.5-6.8) then orthophosphate is optimally available to plant roots. Highly acidic or basic soils have almost no orthophosphate available to the plant, except that which is released from decaying organic matter.

The amount of total phosphorus found in a surface soil can vary greatly, ranging from about 200 kg/ha, in very sandy soils, to about 2,000 kg/ha in soils derived from basic rocks. However, very little orthophosphate is present in the soil solution at any one time, usually <1% of total phosphorus.

Organic matter and associated microorganisms have a strong influence on phosphorus availability. Many forms of phosphorus released from decaying organic matter are readily available for intake by plants. For example, orthophosphate is picked up by fungi and spread throughout the mycelia, and therefore spread throughout the soil. When the fungi die, phosphorus is immediately available to plant roots. Furthermore, many soil microorganisms release acids, which are good at dissolving inorganic phosphorus to become orthophosphate. Finally, mycorrhizae (a type of fungus associated with almost every plant) invade plant roots to extract carbohydrates. In return, the fungi pass on minerals, including orthophosphate, to the roots. Thus, ***Fungi helping roots with phosphorus extraction is analogous to bacteria helping roots by fixing nitrogen***.

Organic phosphorus in most soils may account for as little as 3% and as much as 90% or more of the total phosphorus, but usually represents 30-50% of total phosphorus in most soils.

f. Maintaining enough P in the Soil

Listed below are the best ways to ensure that enough phosphorus is available.

- Keep the pH near neutral
- Assure sufficient water
- Promote high populations of microorganisms by maintaining a good regime of organic matter returning to the soil.

3. Potassium

Potassium (K) is the third major nutrient that farmers often add to soils. Unlike the other nutrients, K is not found inside plant cells, but exists in the fluids that move through the plant. Potassium affects the **osmotic pressure** of the plant by keeping the plant fluids balanced in terms of salts and water movement. When K is deficient, water fills the cells, which in turn become soft, so the plant loses strength. Plants deficient in K tend to be more susceptible to drought, insects and disease.

Potassium is involved in photosynthesis, in the creation of starch in roots, and in the creation of proteins. This is the reason why K is especially critical for root crops.

Plants are better able to absorb potassium compared with P or magnesium (Mg). In fact, ***a plant will absorb as much K as there is available, even if it does not need it***. As a result, too much K causes deficiencies in the other nutrients because the plant becomes too busy taking in K instead of taking in other nutrients, even though it may need the other nutrients more.

Two mechanisms explain why K is not rapidly leached from soils.

- Potassium is very small and gets trapped in cracks in clay particles. As a result, it is not much available to roots.
- It is attracted to the surface of clay particles and organic materials (refer to the see exercise on the structure and function of clay particles).

With a steady program of recycling organic matter, potassium will not be a problem. As an example, almost 98% of the potassium in a rice plant is found in the straw. Therefore, as a general rule, if the carbon-to-nitrogen ratio (C:N) is high, so is the potassium-to-nitrogen ratio (K:N).

Table 5. Deficiency Symptoms

Nutrient	Crop Plant	Deficiency Symptom
NITROGEN	General	Nitrogen deficiencies are most common on soils highly depleted of organic matter, but N is often the most limiting crop nutrient and symptoms can occur in any soil where yearly inputs of N are low.
	Legumes	Since most legumes can supply their own N needs through symbiotic fixation, deficiencies generally do not occur unless the rhizobial symbiosis is not functioning effectively. N-deficient legumes have pale green or yellow leaves, starting with the lower leaves.
	Maize, Sorghum, and Small Grains	Young plants are stunted and spindly with yellowish-green leaves. In older plants, the tips of the lower leaves first show yellowing up the mid-rib in a "V" pattern, or there may be a general yellowing of the entire leaf. In severe deficiencies, lower leaves turn brown and die from the tips onward.
	Vegetables	Tomatoes first show stunted growth and loss of normal green color in the younger, upper leaves; the whole plant gradually becomes light green to pale yellow; veins begin to develop purple color. Flower buds drop and fruits are undersized. Cucumbers and squash first show leaf stunting and a loss of deep green; stems are spindly and fruits are light in color. Other vegetables show a general leaf yellowing.
PHOSPHORUS	General	Phosphorus is most available at pH or around 6.5. Crops growing on very acid or very alkaline soils often show deficiencies. In many acid tropical soils, P is the limiting factor in crop growth.
	Legumes	Phosphorus deficiency symptoms are not well defined in legumes. Stunted grown, spindly plants and dark green leaves are the main symptoms.
	Maize, Sorghum, and Small Grains	Deficiencies are most likely during early growth; stunting is common, without clear leaf signs. Severe deficiencies cause a purplishcolor in corn and sorghum, starting at the tips of the lower leaves (disregard purple stems). Small grains show a bronze coloration instead of purple. Ears from P-deficient maize plants are somewhat twisted, have irregular seed rows, and seedless tips.
	Vegetables	Leaves of most vegetables first fade to a lighter color. Tomato and cabage family plants develop a purple color on the undersides of the leaves or along the veins.
POTASSIUM	General	
	Legumes	In broad leaved legumes like soybeans and field beans, early signs are irregular yellow mottling around the leaflet edges, especially in the lower part of the plant. This turns into a brown, dried margin that may move in to cover half the leaf.
	Maize, Sorghum, and Small Grains	In miaze and sorghum, symptoms are rare the first several weeks of growth. Later, the margins of the lower leaves turn yellow and die, starting from the tip. Potassium-deficient plants have short internodes and weak stalks. Ears from K-deficient maize are often small and may have pointed, poorly seeded tips. It is difficult to dagnose K deficiency in small grains.
	Vegetables	Tomatoes will grow slowly and have a dark blue-green color; theyoung leaves become crinkled; older leaves turn dark blue-green and then develop a yellow-green color around the margins. Fruits may show a blotchy ripening pattern. Cabbage plants first show bronzing at the leaf edges which turn down and dry out.
MAGNESIUM	General	Magnesium deficiencies are most common on acid, sandy soils, or soils that have been limed with a material lacking magnesium.
	Legumes	In early stages soybean leaves become pale green between themain veins and then turn a deep yellow, except at the bases.
	Maize, Sorghum, and Small Grains	In maize and sorghum, a general yellowing of thelower leaves is the first sign; eventually, thearea between the veins turns light yellow to almost white, while the veins stay fairly green. As the deficiency progresses, the leaves turn reddish-purple along their edges and tips starting at the lower leaves and working upward. Symptoms are not clear-cut in small grains.
	Vegetables	Cabbage, cucumber, watermelon, tomato, eggplant, and pepper are the most susceptible. Tomatoes get brittle leaves, which may curl upwards; the veings stay dark green while the areas between turn yellow and then finally brown.

K. Fertilizer and Fertilizer Computation

A fertilizer is any organic or inorganic material of natural or synthetic origin which is added to the soil to supply certain elements essential to plant growth. Fertilizer materials are used to increase the growth rate, yield and quality or nutritive value of plants. For many decades in the past, the term fertilizers practically meant commercial fertilizers of nonliving origin. In recent years, however, increasing attention has been focused on organic and biofertilizers which are biological sources of plant nutrients.

Organic fertilizers or farm manures refer to composts, crop residues, animal manures, green manures, and other municipal or farm waste which supply nutrients and improve soil physical conditions. Organic fertilizers are added to the soil in large quantities to meet nutrient demands of crops. The use of organic fertilizers is a vital component of integrated nutrient cycling systems.

Biofertilizers are microbial inoculants or groups of microorganisms which in one way or another make nutrients available to plants from sources which those plants cannot tap themselves. The nitrogen biofertilizers include Rhizobium (for legumes), the blue-green algae (BGA), Azospirillium, Azotobacter, and Frankia (for non-leguminous trees). The P biofertilizers are made up of bacteria and fungi that solubilize unavailable forms of phosphorus, thus converting them into available forms. Efficient phospho-bacterial isolates have been identified as Psuedomonas striata, P. rattonis and Bacillus polymyra. Among the fungi, the efficient P solubilizers have been observed among the Aspergillus and Penecillium groups. The mycorrhizae constitute another group of biofertilizers in that they increase the absorption of P from the soil and P-fertilizers.

1. Fertilizer Nutrients

Of the known essential nutrient elements that plants obtain from the soil like N,P,K, calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), Zinc (Zn), copper (Cu), the first three are usually limiting to a greater extent than the rest. These nutrients are removed by plants in relatively large quantities so that their depletion proceeds at a faster rate. Besides removal by crop, the supply of these nutrients may also decrease due to leaching, volatization and soil erosion. Thus it is inevitable that fertilizers containing such elements will be needed.

At present most of the soils in the Philippines require one of the three nutrient elements N, P and K. Since they are the nutrients commonly found in fertilizers, these elements are often referred to as the fertilizer nutrients. Most of the fertilizer materials contain other elements in considerable amounts. For example, ordinary superphosphate contains 11.5% S and 19% Ca. There is also evidence showing that micronutrients are limiting the growth of plants on some soils in the Philippines.

The proper usage of fertilizers requires knowledge not only of their properties but also of their effects on soil. The amount of fertilizers to be applied depends on many factors which include the ability of the soil to supply nutrients, the nutrient requirement of the plant, yield potential, other management practices, the capability of the farmer and other environmental factors particularly rainfall. The insufficiency of rainfall which limits potential yield for example, leads to low efficiency of fertilizer use.

The kind and amount of nutrients to be applied to the crop on a given soil can be determined either by field experimentation, soil chemical analysis, plant analysis, observations of deficiency symptoms or a combination of these methods. Field experimentation is the most reliable biological method known. Soil and plant analyses are more effective if used in conjunction with field experimentation while the use of deficiency symptoms requires considerable experience and expertise.

2. Timing of Nutrient Application

Fertilizer should be applied at the proper time to minimize loss of nutrient particularly N and to maintain adequate supply of fertilizer nutrients when plants need them to ensure profitable yield.

If the crop absorbs high proportion of nutrients added as fertilizer efficiency automatically increases. This means that fertilizer efficiency can be increased by getting higher yields with the same amount of nutrient absorbed by the plant. One way to achieve this is to apply the fertilizer at a time to best meet the demand of the rice plant.

Rice plants of medium growth duration (145 days), when grown at low N levels (about 20 kg/ha), use fertilizer most efficiently for grain production during the maximum tillering stage and around the flowering stage (between booting and milking stages). A high nitrogen supply tends to decrease the number of filled spikelets and the weight of 1000 grains. Therefore, split application of N, with one dose at transplanting and another panicle initiation is best for obtaining high grain yields, particularly in the case of medium-season and long-season varieties. N absorbed by the plant from tillering to panicle initiation tends to increase the number of tillers and panicles, and those absorbed during panicle development (from panicle initiation to flowering) increase the 1000-grain weight. The effect of nitrogen topdressing at the early panicle initiation stage on the patterns of N uptake by rice plants almost resembled that of a high level of basal dressing of N. Two to three applications of N per crop give the highest nitrogen efficiency and that more split applications are needed for long-duration varieties and for lighter soils.

Rice, like any other cereals requires a considerable quantity of P for vigorous growth and high grain yield. P is applied to rice at planting. Later application can be made provided it is not later than the time of active tillering. Early application of P is essential for root elongation. P applied during the tillering stage is not efficiently used for grain production. Split application of phosphorus has not been proven of value because, first, there is a great mobility of phosphorus from old leaves to young ones; second, the availability of soil P increases with time during submergence; and third, because leaching losses are low.

Generally, the response of rice to K added to the soil is not as marked as for N or P. There are reports that most rice soils in Asia do not need K as much as N and P and that only a small and variable increase in rice yield is obtained with additional potassium fertilizer.

3. Nutrient Content of Fertilizers

Fertilizers being sold in the market must carry a guarantee of the kind and amount of nutrients they contain. The information is printed on the fertilizer bags or packages. The guaranteed analysis of a fertilizer material expressed in percent following the order: total N, citrate-soluble phosphoric acid (P_2O_5) and water soluble potash (K_2O) is called fertilizer grade. Customarily, the P and K contents are expressed as oxides of the elements. Thus a fertilizer bag with 14-141-14 analysis contains 14% total N, 14% citrate-soluble P_2O_5 and 14% water-soluble K_2O. The relative proportion of the fertilizer nutrients present in a fertilizer is expressed in terms of the fertilizer ration such as 45-0-0 for urea and 14-14-14 for complete.

Table 6. Analysis of Common Inorganic or Commercial Fertilizers.

Material	Percent		
	N	P_2O_5	K_2O
Anhydrous ammonia	82		
Ammonium sulfate	20		
Ammonium phosphate	16	20	
Ammonium chloride	25		
Urea	45		
Superphosphate		20	
Triple superphosphate		48	
Muriate of potash			60
Sulfate of potash			50
Complete	14	14	14

4. Fertilizer Calculations

To supply a certain amount of plant nutrient, the amount of fertilizer to be applied per hectare depends on the composition of the fertilizer materials to be used. Here are some examples on how to determine the amount of fertilizer.

Example 1

a. Ammonium sulfate contains 21 percent nitrogen. This means that 100 kilograms of this nitrogen-carrying fertilizer contains 21 kilograms of nitrogen. To calculate how much ammonium sulfate is needed to supply 120 kilograms per hectare of nitrogen, we simply divide the 120 kilograms of nitrogen needed by 21 percent which is the nitrogen content, and multiply the results by 100.

$$100 \quad x \quad \frac{120}{21} = 570 \text{ kg/ha}$$

This same formula may be used with any of the materials containing nitrogen, phosphorus, or potassium.

Example 2

If one wants to apply 80 kilograms per hectare of phosphorus (P_2O_5) as a single superphosphate (20% P_2O_5), the computation appears below:

$$\frac{80}{20} \times 100 = 400 \text{ kg/ha}$$

b. How to calculate the percentage of fertilizer elements from known amounts of fertilizer materials?

To determine the analysis of a fertilizer mixture, multiply the quantity of fertilizer by the percentage of N, P_2O_5 or K_20 in it and divide by 100.

Example 1

Given a quantity of fertilizer with the following composition, how will you find the number of kilograms of available nitrogen, phosphate, and potash in the mixture?

- 150kg of ammonium sulfate analyzing 21% N
- 600kg superphosphate analyzing 20% P_2O_5
- 100kg potassium chloride analyzing 60% K_20
- 850 kg total weight

Solution:

520 kilograms of ammonium sulfate (21% N)

$$\frac{520 \times 21\%}{100} = 109 \text{ kg of nitrogen}$$

$$\frac{600 \times 20\%}{100} = 120 \text{ kg of phosphate}$$

$$\frac{100 \times 60\%}{100} = 60 \text{ kg of potash}$$

How will you find the percentage of N, available P_2O_5 and K_20 in the whole mixture?

Solution:

Divide the weight of each plant nutrient by the total weight of the mixture and multiply by 100, thus:

$$N = \frac{31.5 \text{ kg N}}{850 \text{ total wt}} \times 100 = 3.7\% \text{ N}$$

$$P_2O_5 = \frac{120}{850} \times 100 = 14.1\% \; P_2O_5$$

$$K_20 = \frac{60}{850} \times 100 = 7.0\% \; K_20$$

This could be summarized as: Grade = - 3.7 – 14.1 -7.0

c. How to calculate the amounts of fertilizer materials to make up a fertilizer mixture of certain percentages of fertilizer elements.

Given the following fertilizer materials with their corresponding available nutrients, How will you find the amount each of the plant nutrients is needed in making 2,000 kg of a fertilizer with a grade of 12-24-12?

- Urea analyzing 45% N
- Triple superphosphate analyzing 50% P_2O_5
- Muriate of potash analyzing 60% K_20

Solution:

2,000 x .12 = 240 kg on N needed
2,000 x .24 = 480 kg of P_2O_5 needed
2,000 x .12 = 240 kg of K_20 needed

How will you find the number of kilograms of each of the fertilizing materials needed to make the mixture (This is the same procedure as A)?

$$N = \frac{240 \text{ kg N}}{45\% \text{ N}} \times 100 = 533\text{kg of urea needed}$$

$$P_2O_5 = \frac{480}{50} \times 100 = 960 \text{ kg of triple superphosphate}$$

$$K_20 = \frac{240}{60} \times 100 = 400 \text{ kg of potassium chloride}$$

Note: Since you wanted 2,000 kg of fertilizer with a grade of 12-24-12, you must add sand or some other insert filler to make the desired weight of which:

533 kg urea
960 kg triple superphosphate
400 kg potassium chloride
107 kg sand, or coconut shells, etc.

2,000 kg – Total

d. Calculation of Mixed Fertilizers

Example 3

Find out the number of kilograms of the separate fertilizer materials needed for the preparation of one metric ton (1,00kg) of mixed fertilizer of 5-8-12 grade using ammonium sulfate (20% N), calcium superphosphate (16% P_2O_5) and muriate of potash (60% K_20).

Work out the quantities of the individual fertilizers required for 100 kg of 5-8-12 fertilizer mixture, i.e., to contain 5% N, 8% P_2O_5 and 12% K_20. Then multiply these figures by 10 obtain the total requirement of fertilizers for 1,000 kg of the mixture.

For N = $\frac{5 \times 100}{20}$ = 25 kg ammonium sulfate

P_2O_5 = $\frac{8 \times 100}{16}$ = 50 kg calcium superphosphate

K_20 = $\frac{12 \times 100}{60}$ = 20 kg muriate of potash

95 kg of straight fertilizers
+5 kg of filler

100 kg of mixed fertilizer

For preparing 1,000 kg of a fertilizer mixture of the 5-8-12 grade, 250 kg of ammonium sulfate, 500 kg of calcium superphosphate, 200 kg of muriate of potash and 50 kg of the filler are needed.

Example 4

Find out the quantities of the individual fertilizers and filler needed to make up a metric ton of 10-10-15 fertilizer mixture using urea (45% N), and ammonium chloride (26%N) in equal quantities, calcined phosphate (30% P_2O_5) and sulfate of pitash (50% K_20).

Work out the quantities of different fertilizers required for 100 kg of 10-10-15 fertilizer mixture and multiply these figures by 10 to obtain the total requirement of different fertilizers, to make up one metric ton of the mixed fertilizer.

Since N is to be supplied in equal parts through urea and ammonium chloride, 10 kg of N in every 100 kg of mixture should contain 5 kg of N from each source.

For N

$$N = \frac{5 \times 100}{45} = 11.1 \text{ kg urea}$$

$$N = \frac{5 \times 100}{26} = 19.2 \text{ kg ammonium chloride}$$

$$P_2O_5 = \frac{10 \times 100}{30} = 33.3 \text{ kg of calcined phosphate}$$

$$K_20 = \frac{15 \times 100}{30} = 30.0 \text{ kg of sulfate of potash}$$

93.6 kg of straight fertilizers
\+ 6.4 kg of filler

100.0 kg of mixed fertilizer

For preparing a metric ton of mixed fertilizer of the 10-10-15 grade, the following quantities of straight fertilizers and filler will be required:

Urea	= 11.1 x 10 = 111 kg
Ammonium chloride	= 19.2 x 10 = 192 kg
Calcined phosphate	= 33.3 x 10 = 333 kg
Sulfate of potash	= 30,0 x 10 = 300 kg
Filler	= 6.4 x 10 = 64 kg
	1,000 kg or one metric ton

Example 5

In this example, one of the straight fertilizers supplies two plant nutrients. Prepare 500 kg of an 8-12-12 fertilizer supplies in which half of the nitrogen is in the form of ammonium sulfate (20% N) and mono-ammonium phosphate (11% N and 40% P_2O_5). P_2O_5 and K_2O are to be added in the form of ordinary superphosphate (20% P_2O_5) and muriate of potash (60% K_2O), respectively.

Eight kilograms of nitrogen in every 100 kg of mixture are supplied with:

4 kg N in ammonium sulfate
2 kg N in ammonium chloride
2 kg N in mono-ammonium phosphate

For N

$$N = \frac{4 \times 100}{20} = 20.0 \text{ kg ammonium sulfate}$$

$$N = \frac{2 \times 100}{26} = 7.7 \text{ kg ammonium chloride}$$

$$N = \frac{2 \times 100}{11} = 18.2 \text{ kg mono-ammonium phosphate}$$

Since mono-ammonium phosphate contains N and P_2O_5, 18.2 kg of mono-ammonium mixed in every 100 kg of mixed fertilizer will also be added.

$$\frac{18.2 \times 40}{100} = 7.28 \text{ kg of } P_2O_5.$$

This means that out of 12 kg of P_2O_5, 7.28 kg are supplied while the remaining 4.72 kg come from ordinary superphosphate.

For P_2O_5 and K_2O:

$$P_2O_5 = \frac{4.72 \times 100}{20} = 23.6 \text{ kg ordinary superphosphate}$$

$$K_2O = \frac{12 \times 100}{60} = 20.0 \text{ kg of muriate of potas}$$

Thus, the quantities of the various fertilizers required to prepare 100 kg of an 8-12-12 fertilizer mixture are:

20.0 kg ammonium sulfate
7.7 kg ammonium chloride
18.2 kg mono-ammonium phosphate
23.6 kg ordinary superphosphate
20.0 kg muriate of potash

89.5 of straight fertilizers
\+ 10.5 kg of filler

100.0 kg of mixed fertilizers

L. Soil Sampling and Soil Analysis

The accuracy of the fertilizer recommendation depends to a large degree on the correctness of collecting representative soil samples. If the field is uniform, a sample may be taken to represent up to 10 hectares of land. One has to make as many borings as possible to cover the whole area. All the soil borings are then mixed and a one-kilogram composite sample is taken. The composite sample is sent to the laboratory for analysis. It should be noted that out of the one kilogram soil sample representing an area of as much as 10 hectares, only a few grams are used in the actual analysis.

Soil analysis can be done using a simple tool or Soil Test Kit (STK) for qualitative analysis for soil pH, nitrogen, phosphorus and potassium or by running a complete chemical analysis in the soil laboratories. Both these tests are tools to help farmers make decisions on how best to prepare the land to provide what the plants need. The result of the analysis is only a piece of information used by technologies in making fertilizer recommendations. This information however, is not sufficient for the farmers to arrive at an intelligent decision. It should go hand in hand with field experiments or trials and with proper understanding of the different aspects of crop production both biotic and abiotic factors.

1. Proper Soil Sampling

The main objective of soil sampling is to collect a small amount of soil sample weighing about one half kg that will represent the soil in a large area, e.g., one hectare furrow slice that weighs about 2 million kilogram. Since only a small amount of soil sample is used in chemical analysis and results are projected for a large quantity of soil, the accuracy of soil testing depends largely on proper soil sampling.

The rooting habit of plants must also be considered. For crops with shallow rooting depth, samples collected from the surface layer (20-30 cm) will suffice. For deep-rooted crops soil samples must be collected up to the subsoil (approximately 20-26 cm).

Using the most common farm tools and materials such as shovel or spade, knife or trowel, small pail and plastic bags, the following are steps on proper soil sampling technique.

a. Make a map of the Farm showing Sampling Areas (SA).

Divide the farm into sampling areas. Each sampling area should be more or less uniform in cropping history, past lime and fertilizer treatments, slope degree of erosion, soil texture, and color. Each SA should not be more than 5 hectares.

b. Collect Spot Soil Samples from each Sampling Area.

In each sampling area dig from 5 to 10 pits and collect sample in each pit. The number of spot soil samples depends on the size of the sample. A spot sample is taken in the following manner:

1) Before digging the pit, clear the soil surface of litters and vegetation.
2) Using spade or shovel, dig a pit to a depth of 20-30 cm.
3) From one vertical side of the pit, take a slice of soil 2-3 cm thick with a single downward thrust of the spade. Using a knife or a trowel, trim the slice of soil on both sides to a bar 3-4 cm width.
4) Place this bar of soil (representing one spot soil sample) in a pail or any suitable clean container.

5) If subsoil sample is needed, take a bar of soil from the succeeding 20 to 30 cm soil depth. The subsoil and surface sample should be placed in separate containers.
6) Cover the pit and move to another spot.

c. Take Composite Soil Sample

After collecting all the spot soil samples of a particular sampling area, pulverize, mix thoroughly and remove stones and fresh leaves from the soil in the container. Place the composite soil sample (about ½ kg) in a clean plastic bag. After that, the composite soil sample, which represents the soil of the sampling area, is now ready for chemical analysis using a STK. This may also be sent to a soil testing laboratory with pertinent label and information.

1) **Precautions in soil samples**

a) A sample should not represent more than ten hectares.
b) One sample should include only areas which appear uniform with respect to the following:
   - Past lime, fertilizer, or manure treatments
   - Low spots
   - Slope and degree of erosion
   - Cropping history
   - Soil texture
   - Organic matter content
   - Color
c) Avoid unusual area as gullies, bare spots, or old fertilizer bands. If sampled, do them separately. ***Do not mix different soils***.

2) Supply soil and crop data

It is important that the soil technologists who make the recommendation know the past management practices used on the land and the proposed crop to be grown. The farmer should send the following information along with the soil sample.

a) Kinds of crops grown during the preceding 3-5 years
b) Crop intended to be grown or planted
c) Kind and amount of fertilizers used in the past
d) Time when the soil was last limed
e) Slope and extent of erosion

3) Conduct a chemical test

Most soil testing laboratories conduct analyses on pH and or lime requirement, phosphorus, potassium, calcium, magnesium, organic matter, nitrogen in various forms, and certain trace elements.

a) Soil pH

This is an important characteristic of the soil since it gives a relative measure of the availabilities and proportions of the nutrient elements present in the soil. It is also needed to determine when to add lime.

b) Soil N

This is to determine the available N in the soil. However, nitrogen releases in the soil is greatly affected by environmental factors.

c) Soil P

The soil phosphorus test determines the available phosphorus in the soil in the calcium phosphate form.

d) Soil K testing

Soil K testing aims to measure the exchangeable potassium level. Maintenance of a high level of exchangeable potassium is highly desirable for assurance of high yields.

Interpretation and Recommendation

The most critical part in any soil test is making the recommendation. In doing this, one needs to consider the following information:

- Past cropping and fertilizer history
- Physical properties of the soil such as texture, slope and internal drainage.
- Results of the chemical tests.
- Crop to be grown next.
- Results of the fertilizer experiments conducted on soils of similar texture.
- Yield level.

M. Seedbed Preparation and Management

Seedbed preparation and management is the single most important factor in the success of any vegetable planting. The seedbed must be smooth and weed free. Weeds will compete with seedlings for nutrients, water and sunlight. If not controlled they can considerably delay the growth and maturation of the seeds. A smooth, clump-free seedbed will guarantee firm contact between the soil and seed, thus enhancing seed germination.

1. Steps when Preparing the Seedbed

The most important single factor in preparing a good seedbed is timeliness - choosing the right time to plow, the right time to disc, the right time to harrow. Methods of preparing a good seedbed vary with different soils, so one must select from the four steps below, the operations which most nearly fit the soil:

a. Clear off all heavy trash and crop residue -such as cornstalks, dried-up tomato vines, rocks, branches, etc. This removes old, diseased plants that harbor insect pests, and makes it easier to work the ground. It is good practice to turn under green manure crops.
b. Plow in light soils such as sandy loams and silts. Plow in heavy soils containing large amounts of clay.
c. Disc plowed the ground immediately so as not to give it the chance to get hard and dry after plowing.
d. Harrow disc ground to level.

2. Some Recommended Seedbed Preparation and Management Practices

a. Soil Sterilization

There are several ways of sterilizing soil, both as a preventive measure against soil-borne diseases (such as damping-off) and as a method to control soil-borne diseases already present. A number of common practices is briefly described below.

- Burning Organic Material on the Soil

A common method of soil sterilization is heating up the soil. The high temperature will cause the death of many micro-organisms, including pathogens on the top of the soil and insect pests with soil-dwelling stages, such as cutworms. Soil sterilization is commonly practiced by burning straw, or dry grass, leaves or waste materials on the nursery beds before sowing. It should be noted that straw burns very shortly and the heat does not penetrate deep enough into the soil. This may result in only a very thin layer of the soil being sterilized A substantial amount of slow-burning but high temperature output material would be required on the soil, e.g. wood rather than grass. Rice husk is preferred to straw because it burns slower and heat penetrates deeper into the soil, resulting in better sterilization.

- Solarization

Another soil sterilization method is solarization – with the help of the sun. Solarization of seedbeds can control soil-borne diseases, weed seeds and some nematodes including rootknot nematodes. However, not all pests are controlled.

To solarize soil, the soil is covered with clear polyethylene or plastic sheets. The best time is during the hot season, when there is plenty of sun. The sun heats up the soil through the plastic and the plastic sheet keeps the heat inside the soil. Usually, the sheets should be left on the soil for at least 4 weeks, depending on the season (hours of sunshine and temperature) and the area (lowland or highlands). The soil should be moist before the plastic sheets are placed and the sheets should be properly fixed on the sides to avoid loosing heat. There is also a need to check the polyethylene sheets for holes and to repair them where necessary. Ploughing the soil before applying the sheets seems to help break up crop left-overs and bring nematodes to the surface so the heat can destroy them. The soil should also be allowed to cool down for a few days before sowing the seeds.

Solarization can be combined with another soil sterilization method. With this method a large amount of organic material is incorporated into the soil before applying the plastic sheets. A better sterilization effect may be obtained and organic material may be added to the soil to improve soil structure and fertilization.

- Use of Sub-soil

When damping-off diseases is a problem in an area, and there is no possibility to shift the nursery to another site, the use of sub-soil may be an alternative to reduce the chance of damping-off disease.

This method is practiced in some parts of Indonesia and is found to have very good results. Since most of the damping-off causing organisms live on top layer of the soil, the top layer of the soil must be removed about 30 cm in an area close to the nursery bed. It is recommended to mix the sub-soil with some compost.

- Biofumigation

Soil-borne pests and pathogens can be suppressed by chemical compounds that are released during decomposition of certain crops. This is called biofumigation. The chemical compounds that are able to kill or suppress pathogens are principally **isothiocyanates**. Those crops with biofumigation potential are used as rotation crop, a companion or a green manure crop.

- Biological Soil Sterilization

Another relatively new method of soil sterilization, comparable with biofumigation is being studied where soil sterilization is achieved by micro-organisms that occur naturally in the soil. It requires air-tight plastic sheets. The fresh plant material (from previous crop or green manure) is worked into the soil deep and homogeneous. The field is watered and covered with an air-tight plastic sheet (0.12-0.15 thick), properly fixed at all sides. The sheet is left on the field for 6-8 weeks.

Within a few days of applying the plastic sheet, the oxygen, the micro-organisms cannot break down the organic material the usual way (into carbon (CO_2 and water or H_2O) so they switch to fermentation. During this fermentation, several degradation products are formed and after some time, a biogas called methane, is formed. Also, the concentration of carbon in the soil increases. The fermentation products, the biogas methane and the carbon are thought to play an important role in the suppression of some soil pathogens and nematodes. The effects are better at higher temperatures.

Similar studies showed that biological soil sterilization has been effective against the many soil-borne fungi: *Fusarium oxyporum, Rhizoctonia solani* and *R. tuliparium, Verticulium dahliae, Sclerotinia sclerotiorum* and different nematode species (*Meloidogyne* and *Pratyenchus*)

- Boiled Water

Although not scientifically proven the use of boiling water for soil sterilization may be an option for soil sterilization. A farmer from Bangladesh used this method. First, he boiled water and poured it one to three times over the nursery soil to kill pathogen and possibly insects and/or nematodes in the seedbed. Then, he let the soil drain and cool down before sowing the seeds.

b. Seeding

Seed should be applied using a hand spreader to disperse the seed uniformly. The easiest way to apply seed uniformly is to spread the seeds in one direction. It might take three or more passes in a single direction, but it is well worth the time to get a uniform seeding.

After the starter fertilizer and seed have been applied, the area should receive a light raking followed by a light rolling to insure good seed-soil contact. It is critical to maximize the seed-soil contact for quick germination and establishment

c. Mulching

Mulch is any substance spread on the ground to protect plant roots from heat, cold or drought or to keep fruit clean. Mulching the garden shows that a farmer or gardener really care about the plants.

Mulching the area will prevent erosion and conserve water. Therefore, mulching is most important when it is impossible to adequately irrigate newly seeded areas. Apply mulch which will shade seedlings and have to be raked off later. Apply the mulch very lightly so you can still see approximately 50% of the soil through the mulch layer.

Mulching is a long established horticultural practice. Farmers know that shallow cultivation of the soil's surface after a rain slows the rate of water loss from the soil. The shallow layer of dry surface soil acts as a mulch.

Mulches can be classified as inorganic or organic. Inorganic mulches include plastic, rocks, rock chips and other non-plant materials; whereas, organic mulches include straw, compost, sawdust and similar materials. Plastic is the only inorganic mulch used in vegetable gardens.

Value of Mulches

A thin layer of mulch on the soil surface (especially in sloping gardens) reduces the washing away of soil particles by rushing water. Also, mulches prevent raindrops from splashing on the soil surface. See figure 1.

Figure 1

Saving soil moisture is an important use of mulch. A mulch layer on the soil surface allows the soil to soak up more water. Mulch also reduces the rate of water loss from the soil. A 3-inch layer of mulch on the soil surface dries much faster than the soil below it. Thus it prevents water from moving into the air. See figure 2.

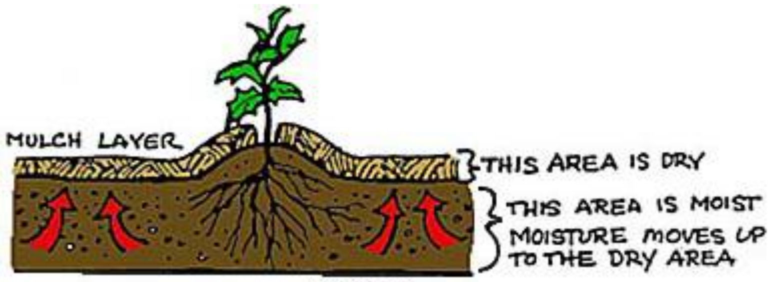


Figure 2

Mulches modify soil temperature in vegetable gardens.

Proper mulching in summer months keeps the soil cooler. Soil covered by black or clear plastic or dark organic mulch in early spring warms faster than bare soil. This allows earlier planting of warm-season crops. See figure 3.

Figure 3

Use light-colored paper such as newspaper in summer to keep the soil cooler. Organic mulches such as compost and sawdust also keep soil below the mulch layer cooler in summer. Dark soil warms much faster than light-colored soil. See figure 4.

Organic mulches enrich the soil as they decay and provide a better environment for plant growth. Soils that have high organic matter are easier to till and better suited to vegetable gardening. Adding organic material makes soils more crumbly, especially clay soils that pack and crust.

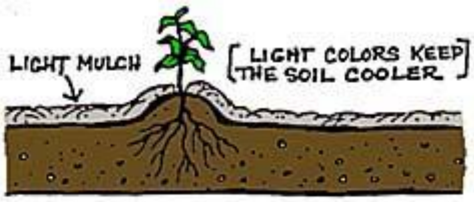


Figure 4

Mulches help plants by gradually increasing soil fertility. Organic mulch such as straw or newspaper can be turned under the soil at the end of the season. This helps build the soil's organic matter content. Turn the mulch under as soon as the gardening season is over so it breaks down before the garden is replanted.

Most mulch also provides excellent weed control. Mulches do not prevent weed seeds from sprouting. However, weed seedling emergence is blocked by a mulch layer thick enough to exclude light. A 3-inch layer of mulch on the soil surface keeps most annual weed seedlings from coming through (see figure 5). Weeds that bread through are removed more easily from mulched soil.

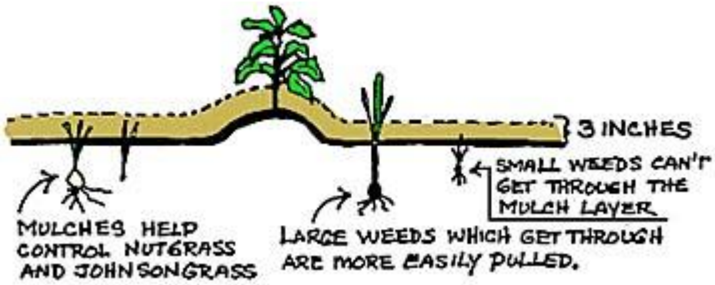


Figure 5


Figure 6

A well-mulched garden can yield 50 percent more than an unmulched garden the same size. Space rows closer since there is little or no need to cultivate the soil. Plant food is more available in cooler soil, and the extra soil moisture increases plant growth and yields. There will be more fruit harvest because of less fruit rot. This is because the fruit does not touch the soil, and the soil is not splashed up on the fruit. See figure 6. This is true for tomato fruits that rot easily when resting on the soil surface. Potatoes can be mulched heavily as the vines grow. This causes tubers to form in and under the mulch layer. On the other hand, potatoes are less susceptible to soil rot. They are easier to harvest and less likely to be bruised during harvest.

Garden mulching reduces maintenance. A good mulch layer eliminates the need for weeding, and mulched vegetables are cleaner at harvest time. For example, the fruits of tomato, melon and squash plants never touch the soil so they are a lot cleaner.

Mulching Materials

Many materials are available for mulching a garden. Some examples are: compost, straw, gin trash and sawdust.

- **Compost** is generally the best mulching material for the home garden. It is usually free of weed seeds and is inexpensive. It is not necessary to purchase expensive materials for mulching. Prepare compost

Figure 7

from materials present in your yard.

- **Straw** is short lived and coarse textured. More straw is needed for the same effect as compost or lawn clippings. Generally, less of the finer-textured materials is required to provide a 3-inch layer of mulch after settling. Compost, however, usually requires only about 4 inches to provide a 3-inch mulch layer.
- **Sawdust** is commonly available especially in East Texas. If well managed, it can be a good mulch. It can result in a temporary, but sharp, decrease in soil nitrogen. Add a small amount of garden fertilizer to the soil after applying sawdust directly to a garden. Even better, add nitrogen to sawdust, then compost it before spreading it on your garden.
- **Plastic** is effective mulch if used properly. Use black plastic in the spring and early summer to warm the soil. Black plastic keeps light from the soil and prevents weeds from growing. Clear plastic warms the soil, but weeds can grow beneath the plastic. A disadvantage of plastic is that it cannot be turned into the soil at the end of the season. See figure 7.

Selection of Mulching Material

When selecting materials, consider these factors:

- **Cost of the material.** Do not spend money on mulching material when suitable materials are available at little or no cost.
- **The crop you plan too much.** Never use material from the crop that is to be protected. For example, do not use potato vines from the spring crop to mulch fall potatoes because the possibility of disease is increased.
- **When the mulch is to be used.** Select light-colored mulch during the summer to reflect heat. Use dark-colored mulch in early rainy season to help warm the soil and to permit earlier planting and hasten early growth.

Using Mulches

Spread mulches on freshly cultivated, weed-free soil before plants are large enough to interfere. Apply organic mulch thick enough to leave a 3-inch layer after settling. Four inches of fine materials like compost should be adequate. Remember that coarser materials, such as straw, settle and may require 6 inches or more initially. If you use newspaper, place three layers on each side of the row. See figure 8. Add more mulch during the season when working with organic materials. The mulch settles and gradually rots during the growing season where it meets the moist soil surface. Adding additional layers assures continuous weed control and a clean resting place for the fruits of your labor and creates a pleasing appearance all season long.

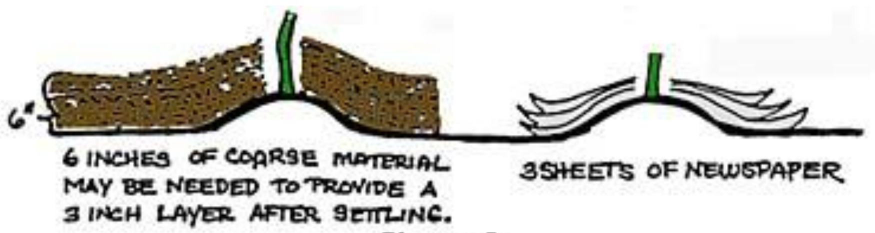


Figure 8

d. Watering

The seedbed should not be allowed to dry. A newly seeded lawn will need to be irrigated two to four times daily depending on the weather. Enough water should be applied to moisten the top one to two inches of the soil profile, but avoid over-watering and saturating the area. Once the seedlings are two inches high, gradually reduce the frequency of irrigation and ensure that the water is deeper.

e. Fertility

New seedlings have poorly developed root systems and thus they cannot effectively absorb nutrients from the soil. Therefore, it is important to **fertilize** frequently after seeding to encourage establishment.

O. Composting

1. What is Compost

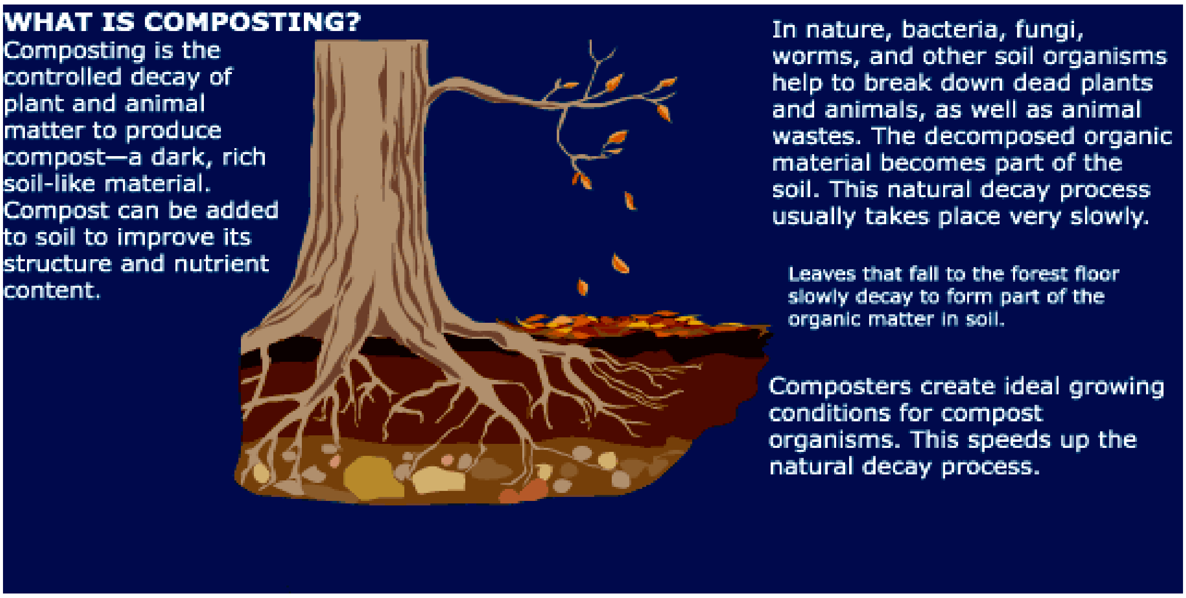
Compost is a mixture of decayed organic materials decomposed by microorganisms in a warm, moist, and aerobic environment, releasing nutrients into readily available forms for plant use.

2. Why use Compost

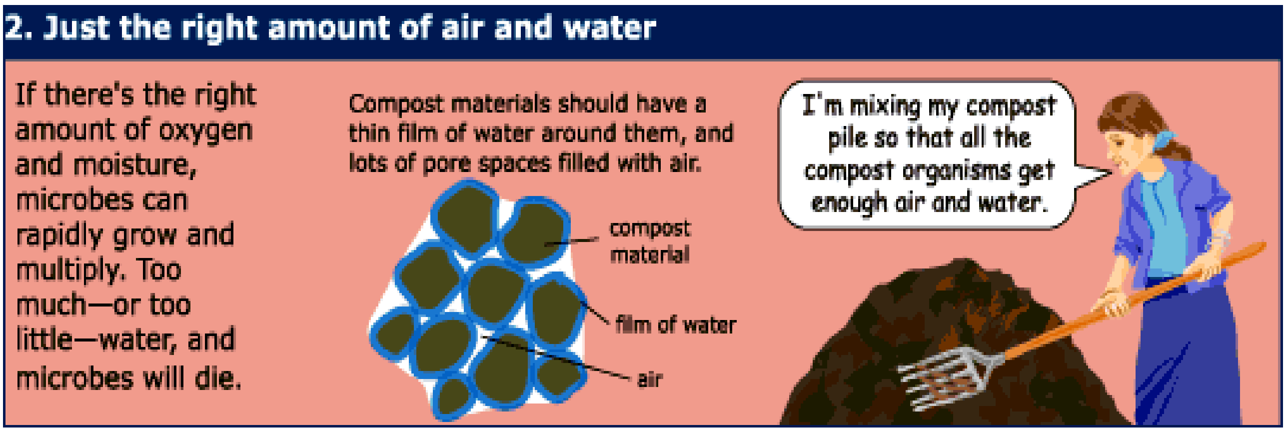
- There is a need for sustainable production through integrated nutrient management.
- Compost produces less methane than uncomposted rice straw when incorporated in the soil.
- It solves problem of declining yield.
- It also correct micronutrient problems like zinc deficiency.

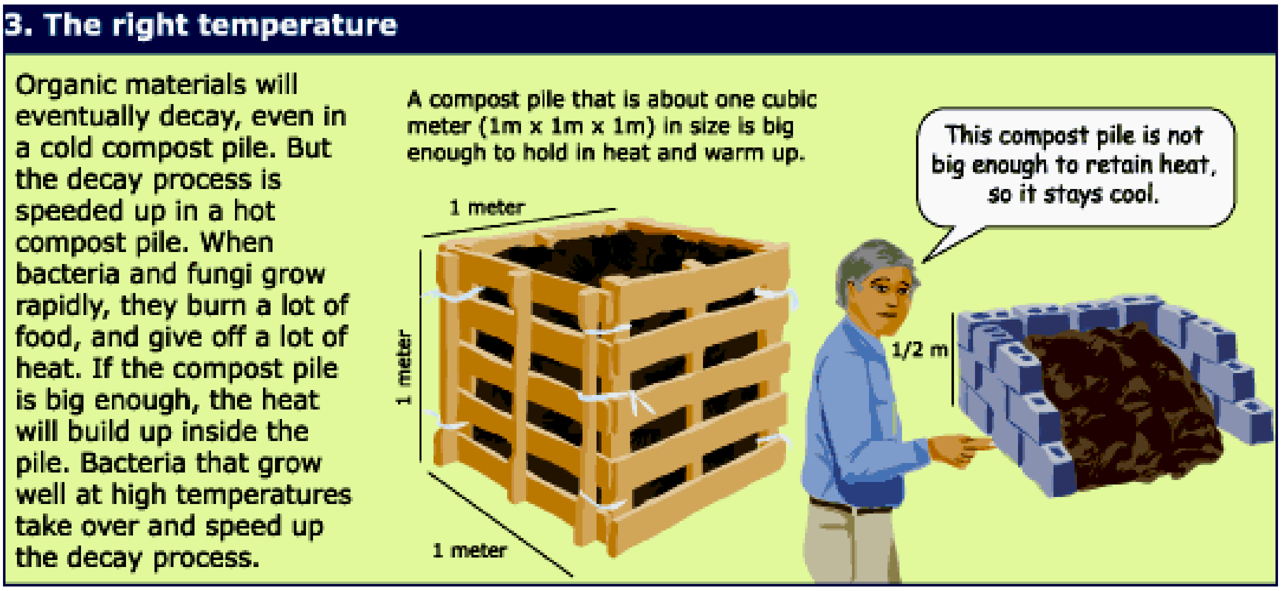
3. What are the Benefits of Compost

- Ensures big savings, increased farmer self-reliance
- Increases yield
- Improves water-holding capacity of the soil
- Improves aeration
- Provides humus or organic matter, vitamins, hormones and plant enzymes which are not supplied by chemical fertilizers
- Acts as buffer to changes in soil pH
- Kills pathogenic organisms, weeds, and other unwanted seeds when a temperature of over 60°C is reached
- Mature compost quickly comes into equilibrium with the soil
- Different materials can be blended or mixed together which can increase the nutrient content of the compost fertilizer


WHAT IS COMPOSTING?
Composting is the controlled decay of plant and animal matter to produce compost—a dark, rich soil-like material. Compost can be added to soil to improve its structure and nutrient content.
In nature, bacteria, fungi, worms, and other soil organisms help to break down dead plants and animals, as well as animal wastes. The decomposed organic material becomes part of the soil. This natural decay process usually takes place very slowly.
Leaves that fall to the forest floor slowly decay to form part of the organic matter in soil.
Composters create ideal growing conditions for compost organisms. This speeds up the natural decay process.


WHAT COMPOST ORGANISMS NEED
1. A balanced diet of compost materials
"Browns" are compost materials that are brown and dry.
sawdust
leaves
straw
"Browns" are high in carbon, which is energy food for microbes.
"Greens" are compost materials that are green and moist.
kitchen waste
grass cuttings
"Greens" are high in nitrogen, which microbes need to make proteins.
If I add about 3 parts browns to 1 part greens, then the compost organisms will have a balanced diet.


2. Just the right amount of air and water
If there's the right amount of oxygen and moisture, microbes can rapidly grow and multiply. Too much—or too little—water, and microbes will die.
Compost materials should have a thin film of water around them, and lots of pore spaces filled with air.
compost material
film of water
air
I'm mixing my compost pile so that all the compost organisms get enough air and water.



4. **Three Ways of Making Compost**

a. Traditional Method

This is a slow process, requiring 3-4 months before farm wastes are fully decomposed and ready for use as compost fertilizer. This means that the fertilizer can only be used after one planting season. This also requires a bigger composting area. However, this method involves only eight steps, and it is inexpensive to produce, requiring no extensive input except labor.

b. Rapid Method

With the aid of fungus activator *Trichoderma harzianum*, decomposition of farm wastes is accelerated to just 3-4 weeks. This means that the compost can be used in the next planting season. This involves ten steps.

c. Bio-Enriched Method

Employing both a fungus activator and a nitrogen-fixing bacteria, farm wastes are first decomposed by *Trichoderma* sp. for 2-3 weeks, after which the resulting compost is inoculated with live N-fixing bacteria *Azotobacter sp.* Incubation for 1 week produces a nitrogen-enriched compost that can supply a rice crop's total N requirement, depending on the material used, soil condition, and planting season. This involves 10 steps.

Note: For the Rapid and Bio-Enriched Methods of composting, procedures in preparing these microorganism activators are available at the Institute of Molecular Biology and Biotechnology (BIOTECH) of the University of the Philippines Los Baños (UPLB) College, Laguna; and the Department of Science and Technology (DOST).

5. **How to Make Compost**

a. Make the soil firm, and dig a trench around for excess water to flow into.
b. Stack up about six (6) inches high: grass; do not compress.
c. Put over the grass about 1-2 inches thick of animal manure. Urea or ammonium sulfate, about 1-2 kilos may also be used if available.
d. Put one-inch thick of rich soil mixed with wood ashes, lime over the pile.
e. Repeat the process over the pile until about 1 1/2 meters high.
f. Water the pile to make it moist.
g. Thrust a pipe(s) or bamboo pole(s) with holes to allow air to penetrate the bottom of the pile.
h. After three weeks, turn the compost over with the aid of a garden fork. This is easily done by transferring into another pile so that the bottom layer will now be on top, etc.
i. Turn the compost again bottom up after 5 weeks. Wait for 4 weeks more to allow complete composting.
j. In hot weather, the compost must be watered. In rainy days, cover the compost with banana leaves.
k. The pile of compost will be hot. This means that the bacteria in it are working.
l. Composting can also be hastened with a chemical for this purpose.

6. **Making Compost in 14 Days**

Nutrients in the soil get depleted gradually, so it is necessary to replenish these with fertilizers. Natural fertilizers can be made without expenses, and their uses does not harm the environment.

As farm wastes decompose, the carbon and oxygen mixed together cause the wastes to heat up. Thus, six (6) part of straw and grasses (which are rich in carbon) are mixed with one (1) part nitrogen-rich materials like ipil-ipil, hagonoy, chicken manure and the like.

Materials

- Farm wastes: leaves, straw, hull, grasses/weeds) fresh and dried)
- Fresh animal manure: carabao/cow/horse/chicken manure, etc.
- Kerosene can or basket
- Eight (8) pieces posts from ipil-ipil, about 2" - 3" diameter, 5' high
- Bamboo
- Shovel, garden fork, bolo

Procedure

a) Select a shady place in your yard that is somewhat elevated and does not lodge water.
b) Enclose about 5 ft square around the post; allow space for air at the bottom.
c) Preparation
First day
    - Cut up into about 3" 4" the farm wastes
    - Wet these or soak for 5minutes in water. If they are plenty, spray water on the mound.
    - Mix with equal amount of fresh animal manure; mix them well.

- Stack up the enclosed place with this until 4-ft high.

Second day
- See if the pile is getting heated up. If not, sprinkle with dissolved fresh manure. It is important to have this heat within 24-48 hours. This heat will kill the microbes (especially if manure is used together with the seeds of weeds and grasses).

Third day
- Reverse the pile; see if it is heating up. Keep it moist but not wet. If it is still not hot, sprinkle with dissolved manure.

Seventh day
- Reverse the pile again; see if it is heating up. Keep it moist.

Tenth day
- The pile must be cooling at this point, which means the compost is done.

Fourteenth day
- The resulting compost is ground (pulverized), dark and course soil. If desired, let it stay longer to decompose longer because the natural bark or coating takes a longer time to deteriorate.

7. Health Precautions

a. The decomposing compost heap can generate heat up to 60^{o}C. Be careful in handling the compost while turning. Wear protective gloves or footgear so as not to scald your hands and feet.
b. Composting materials and microorganisms may cause allergies, although they are non pathogenic. To avoid inconvenience from itching, cover nose and mouth with mask; use long-sleeves, and wash body and hands after working on the compost.

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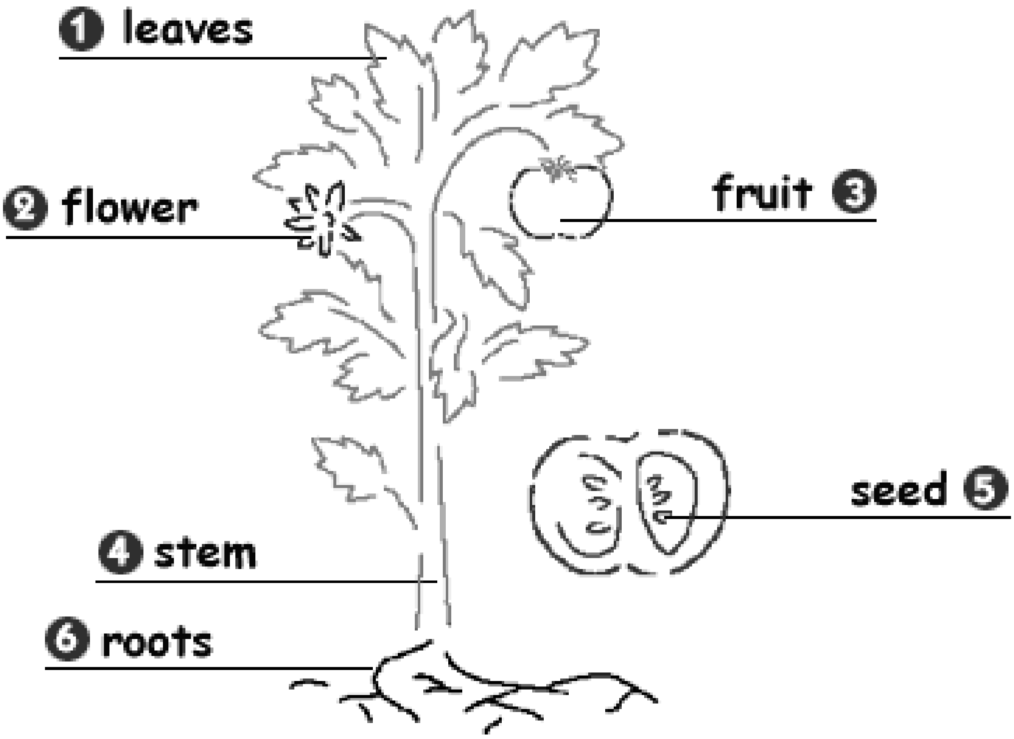
PART IV: PLANT PARTS AND FUNCTIONS

A. Plant Parts and Functions



1. Leaves

Leaves are the food-making factories of green plants. Leaves come in many different shapes and sizes. Leaves can be simple, that is made of a single leaf blade connected by a petiole to the stem (oak, maple), or compound, in which the leaf blade is divided into separate leaflets attached by a petiole to the stem (ash, locust).

Leaves are made to catch light and they have openings to allow water and air to come and go. The outer surface of the leaf has a waxy coating called cuticle which protects the leaf. Veins carry water and nutrients within the leaf.

Leaves are the site of the food making process called **photosynthesis**. In this process, carbon dioxide and water in the presence of chlorophyll (the green pigment) and light energy are changed into glucose (a sugar). This energy-rich sugar is the source of food used by most plants.

Photosynthesis is essential to green plants. Photosynthesis supplies food for the plant and oxygen for other forms of life. A green plant helps make the oxygen human need for survival.

2. Flowers

Flowers not only look pretty but, in fact, are important in making seeds. Flowers have some basic parts. The female part is the pistil. The pistil is usually located at the center of the flower and is made up of three parts: the stigma, style, and ovary. The stigma is the sticky knob at the top of the pistil. It is attached to the long, tube-like structure called the style. The style leads to the ovary which contains the female egg cells called ovules.

The male parts are called stamens which usually surround the pistil. The stamen is made up of two parts: the anther and filament. The anther produces pollen (male sperm cells) and the filament supports the anther.

During the process of fertilization, pollen lands on the stigma, a tube grows down the style and enters the ovary. Male sperm cells travel down the tube and join the ovule to fertilize. The fertilized ovule becomes the seed and the ovary becomes the fruit.

Petals are also important parts of the flower because they help attract pollinators such as bees, butterflies and bats. Tiny green leaf-like parts called sepals also appear at the base of the flower. They help protect the developing bud. Insects and other animals help some flowers become pollinated.

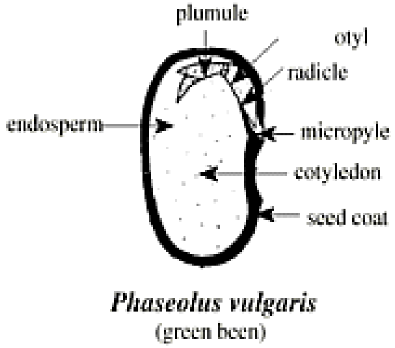
3. Fruit and Seeds

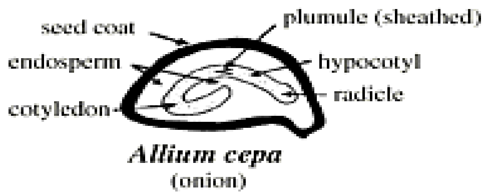
The fruit is the ripened ovary of a plant containing the seeds. After fertilization, the ovary swells and becomes either fleshy or hard and dry to protect the developing seeds. Many fruits help seeds spread (maple seeds). Many things considered vegetables are really fruits (tomato, cucumber, beans).

The seed, or matured ovule is made up of three parts. The embryo is a miniature plant in an arrested state of development. Most seeds contain a built-in food supply called the endosperm (orchid are an exception). The endosperm can be made up of proteins, carbohydrates or fats. The third part, a hard outer covering is called a seed coat. It protects the seed from diseases and insects, and prevents water from entering the seed which would initiate the germination process ahead of the proper time or prematurely.

The endosperm is found in the plant's cotyledons. Plants with one cotyledon (like corn) are called monocots. Those with two cotyledons (like beans) are called dicots. Seeds become the plant's way of getting from one area to another.

Parts of a Seed





4. Stems

Stems carry water and nutrients taken up by the roots to the leaves, and then the food produced by the leaves moves to other parts of the plant. The cells that do this work are called the xylem cells (move water) and phloem cells (move food). Stems also provide support for the plant by allowing the leaves to reach the sunlight they need to produce food.

5. Roots and Plant Vessels

The roots help provide support by anchoring the plant and absorbing water and nutrients needed for growth. They can also store sugars and carbohydrates that the plant uses to carry out other functions. Plants can have either a taproot system (such as carrots) or a fibrous root system (such as turf grass). In both cases, the roots are the links between the water and nutrients needed for plant growth.

Roots can be characterized as -

- Carbon pumps that feed soil organisms and contribute to soil organic matter
- Storage organs
- Chemical factories that may change soil pH; poison competitors; filter out toxins; and concentrate rare elements, etc.
- A sensor network that helps regulate plant growth
- Absorptive network for limiting soil resources of water and nutrients
- Mechanical structures that support plants, strengthen soil, construct channels, break rocks, etc.
- Hydraulic conduits that redistribute soil water and nutrients
- Habitats for mycorrhizal fungi, rhizosphere and rhizoplane organisms

Root Functions

Water Uptake:

Roots take water from the capillary spaces between soil particles. This function is carried out by the young portions of the roots at the location of minimal cutinization of the epidermis and at maximum surface area. This location is found in the root-hair zone just proximal from the growing root tip. Thus roots take in their water through very fine roots located at the drip-line of the plant's canopy.

Mineral Uptake:

Root hairs are responsible for initiating and maintaining action exchange relationships with microscopic soil particles. Here the root hair secretes hydrogen ions onto the soil particle, exchanging them for mineral ions (calcium, magnesium, iron, etc.). Then the root removes those minerals from the soil water surrounding the soil particle.

Conduction of water and minerals:

Roots contain xylem to conduct water from the soil up the plant and out through the leaves. These xylem tracheids and/or vessels are connected to others in end-to-end design allowing soil water and minerals to be lifted up to the leaves. The evaporation of water from the leaves is the major pull of water through the xylem, but roots can also develop "root pressure" osmotically when the soil is well-watered and the plant has sufficient reserves. Evaporation of water from the soil/mineral solution bathing the leaf mesophyll cells concentrates the minerals for use by the plant as enzyme cofactors, etc.

Roots also contain phloem to conduct photosynthate from the leaves to the root tips. The metabolism of roots growing in the dark of the soil is essentially dependent upon respiration. This process requires carbohydrate or other organic molecules as fuel. It also requires a supply of oxygen, which is why soil needs to drain well for good plant growth.

There are two types of vessels in plants:

Xylem -- are vessels that take water and mineral ions from the roots to the stem and the leaves.

Phloem -- takes inorganic substances and sugars from the leaves to the parts of the leaves that require them e.g. the flowers, fruits and roots.

Xylem travels only upwards, whereas phloem travels in both directions.

Movement in xylem vessels

The cells which make up a xylem vessel are dead. They are joined together by a sticky substance called lignin, these cells are therefore said to be "lignified". Lignification causes the xylem vessels to be impermeable.

There are three mechanisms which contribute to the movement of water through the xylem vessel.

- **Capillarity ---** Xylem vessels are often very small in plants and therefore water is able to travel up the vessels through capillary action. The water molecules stick to the side of the vessel and slowly "climbs up". However this mechanism does not account for the greater distance that water can travel in trees.
- **Root pressure ---** Some plants can produce a water potential gradient by actively transporting mineral ions to the top of the plant. The water potential on the top of the plant is much greater than the bottom of the plant, therefore the water moves up to the top.
- **Cohesion-tension ---** As leaves transpire, water evaporates to the dry surroundings outside the plant. Water molecules stick to each other by hyrdogen bonds. This is known as cohesion. While the leaves transpire the water molecules are all pulled up the plant. Water molecules also stick to the sides of the vessel which helps to speed up this mechanism. This is known as adhesion.

B. Seed Germination and Seedling Development

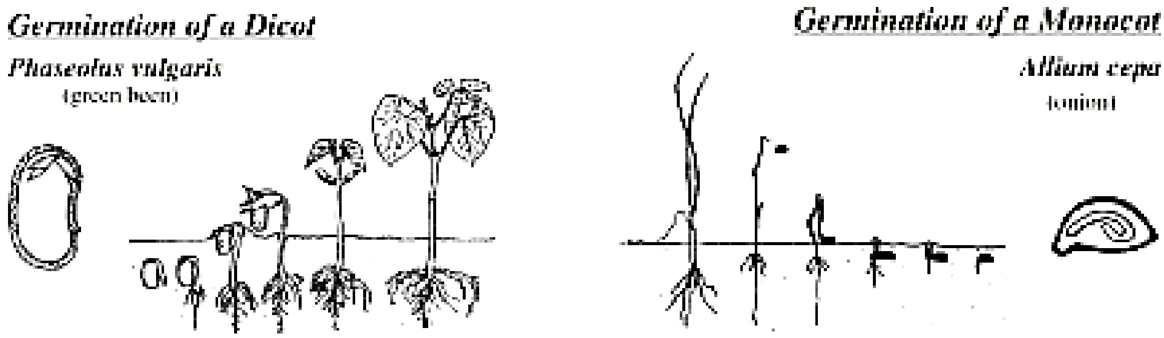
Plants are classified based on the number of seed leaves (cotyledons) in the seed. Plants such as grasses can be monocots, containing one cotyledon. Dicots are plants that have two cotyledons.

Seeds remain dormant or inactive until conditions are right for germination. They need water, oxygen, and proper temperature in order to germinate. Some seeds also require proper light. Some germinate better in full light while others require darkness to germinate.

When a seed is exposed to the proper conditions, water and oxygen are taken in through the seed coat. The embryo's cells start to enlarge. Then the seed coat breaks open and a root or radicle emerges first, followed by the shoot or plumule that contains the leaves and stem.

Many things can cause poor germination. Overwatering causes the plant to not have enough oxygen. Planting seeds too deeply in the soil causes them to use all of their stored energy before reaching the soil surface. Dry conditions mean the plant does not have enough moisture to start the germination process and keep it going.

Some seed coats are so hard that water and oxygen cannot get through until the coat breaks down. Soaking or scratching the seeds will help break down the seed coat. Morning glories and locust seeds are examples. Other seeds need to be exposed to proper temperatures. Apple seeds will not germinate unless they are held at cold temperatures for a period of time.



Seed Germination

Seed is of good quality when more than 70% of the seed germinates and germination occurs within approximately 7-14 days. Irregular germination result in seedlings of different sizes. High germination percentage is especially important when hybrid seed is used because this is often the most expensive input of production.

Most seed companies have their own minimum seed germination standards. For example, an international seed company based in Thailand states that germination of their hybrid tomato varieties is over 80%. Actual germination depends on seed age and storage conditions.

A float test for seed:

A seed usually contains an embryo inside and some food reserve to provide the energy for germination.

When seed is put into water, it is noted that a proportion of the seed sinks and another proportion floats. Seeds that sink have a higher germination rate. It can be expected that the floating seed is not filled well and may not germinate as readily as the sinking seed. By using only sinking seed, the overall quality of a seed lot could be improved.

This method could be used to compare germination rates of floating/sinking seed.

C. Methods of Seed Sowing

Sowing is the most important operation in crop production. The seed must be deposited at required depth i.e. moist zone of soil so as to get optimum condition for its germination. Or sowing is the placing of specified quantity of seeds in soil in the optimum position for its germination and growth,

Too shallow sowing results in thin germination due to inadequate soil moisture at top soil layer. Similarly, if the seeds are sown very deep in the soil, the young seedlings may not able to push their shoots above, through thick soil layer. So that seed must be sown at proper depth and should be properly covered with soil so as to get adequate moisture for its germination. Seeds are sown either directly in the field or in nurseries where they are raised and then transplanted later.

Planting is the process of putting plant propagules (May be seedling, cutting, tuber, rhizome, clones) into soil to grow as crop plants.

Sowing Methods

The method of sowing should depend upon size of seed, type of crop and season. The following methods are generally used for sowing different field crops.

1. Broadcasting

Broadcasting means scattering seeds uniformly by hand all over well-prepared field and then covering the seeds with soil through the help of light implement or plank. Broadcasting of seed is done in dry, semi-dry and wet fields. For sowing of wet fields the seed must be soaked in water for 12 hrs and incubated for a few hours so that the radicle just begin to emerge from seed and then broadcasted by hand uniformly. Broadcasting method is adopted for grain crops, and most leafy vegetables are sown using this method. Crops which require transplanting i.e. paddy, tobacco, onion, cauliflower, cabbage are also sown using this method.

Advantages

1. It is a quicker and cheaper method as far as cost of labor is concerned.
2. Implements are not required for sowing.
3. Skilled labor is not required for sowing.
4. It can be done in moist condition.

Disadvantages

1. It requires more seed per unit area.
2. It is an old method and skilled labor is required for uniform distribution.
3. The seeds fall at different depth resulting in uneven and guppy plant stand as shallow-sown seed may not germinate due to adverse moisture condition and germination of deep sown seed may have adverse effects due to depth.
4. Inter culture operation is difficult as spacing is not maintained.

5. Uneven distribution of seed and hence uneven crop growth resulting in excess competition at certain area and no competition at some areas.
6. Loss of seeds by birds and insects if it is not properly covered with soil.

2. Drilling or Line Sowing

Sowing of seeds in a line on a large scale is generally done with the help of sowing implement such as seed drill or fermium seed drill called drilling. In drilling seeds may be sown continuously or in rows at regular interval. These rows may be straight or parallel. Drilling may be adopted for pure cropping and intercropping. In addition to this ferti-seed drill are also used, where fertilizer and seeds are sown simultaneously at desired depth of soil.

Advantages

1. Seed placement is done at proper and uniform depth resulting into uniform germination.
2. Seed rate requires less as compared to broadcasting method.
3. This method avoids crowding of seedling and maintains uniform spacing between two rows.
4. Inter culture is carried out easily.
5. Plant population can be adjusted.
6. Sowing depth can be adjusted in order to place the seed at moist zone.

Disadvantages

1. It is not possible to maintain plant to plant distance in ordinary seed drill.
2. Requires seed drill for sowing hence it is costly than broadcasting method.
3. Skilled person is required for carrying out sowing operation, if not the seeds are not sown properly which may cause uneven germination and ultimately poor stand of crop.

D. Seedlings

Germination is the resumption of active embryo growth. Prior to any visual signs of growth the seed must absorb water through the seed coat and micropyle. In addition, the seed must be in the proper environmental conditions; that is, exposed to oxygen, favorable temperatures, and for some correct light. The radicle is the first part of the seedling to emerge from the seed. It will develop into the primary root from which root hairs and lateral roots will develop. The portion of the seedling between the radicle and the first leaflike part (plumule), are attached to a structure called the hypocotyl which becomes the stem. The seed leaves and cotyledons encase the embryo and are usually different in shape from the leaves that the mature plant will produce. Plants producing one cotyledon fall into the group of monocotyledons or monocots. Plants producing two seed leaves are called dicotyledons or dicots.

Care of Seedlings

A seed is an embryonic plant waiting to get out. It is the pleasurable task of the gardener to turn the seed from dormancy into a living thing by providing warmth, light, air and moisture.

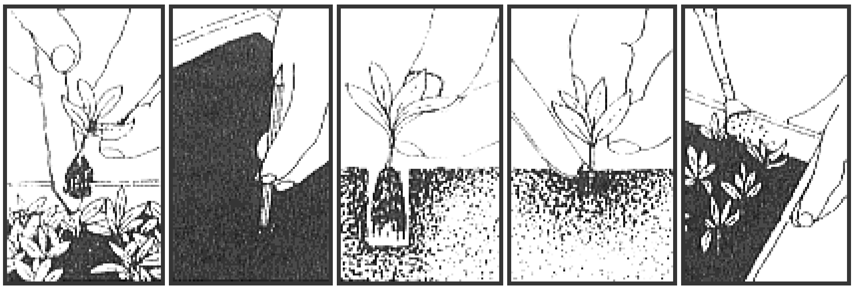
Seeds even have their own food supply to start them off, at least until they can extend roots and draw food and water from the soil.

Some seeds are not quite fussy over the conditions in which they would grow. Many weed seeds fall into this category. Others are so sensitive that they require a carefully controlled environment to germinate. The following practices are recomended when handling seedlings before they are transplanted to the main field.

1. <u>Pricking out</u>

   When seeds germinate the first leaves to appear are the cotyledons or seed leaves. These are usually a pair of oval, fleshy leaves that bear no resemblance to the mature leaves of the plant.

   The conventional practice is that seedlings should not be pricked out or transplanted until the first true leaves appear. In the case of large seedlings, such as eggplants or pechay, this could be before the true leaves have developed and it is sound advice to sow the seedlings individually in small pots.



Gently lever out seedling with as much root as possible
Makes holes in pot or seed tray with a pencil
Hold by seed leaves and drop into tray
Firm soil around seedling with dibber
Water gently with a fine spray

   The rule is never to handle the plants by their stems, which bruise easily, but always by their seed leaves. Some people use a sharpened wood, or a metal device to separate and ease out the seedlings, taking care not to damage the delicate roots.

   It is good to prepare the planting holes in the trays of well-moistened compost before you actually lift out the seedlings from the sowing container. Simply ease each seedling into position with the roots falling neatly into the hole, then gently firm the compost into contact with the baby plant while still holding it by the seed leaf.

2. Hardening Off

   It will be necessary to harden off your seedlings before transplanting them into the garden bed. This is accomplished by placing the seedling outside in a sheltered location. At this point the seedlings are very tender and could easily break by wind and rain. Start out by placing the seedling in full morning sunlight for one hour. Increase the time in full sunlight gradually adding time each day. Protect your seedlings from wind and animals to prevent breakage of the tender vegetation. Within two weeks your plants should be able to stand full sunlight the entire day without wilting or burning the tender leaves. At this point your seedlings are ready for the harsh elements of the garden.

3. Thinning and Roguing

   Some plants with tiny seeds cannot be transplanted. They can be sown along a shallow drill and later some seedlings can be pulled out leaving the seedlings 5 cm apart. This is called thinning. Meanwhile, the process of pulling out diseased or weaker plants is called rouging.

Sources:

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PART V: FAMILIES OF VEGETABLE CROPS

A. ALLIUM FAMILY

The alliums are noxious bulbous perennials with grass-like leaves. Bulbs consist of a short, thick stem axis (basal plate) with a growing point surrounded by fleshy scale leaves. Short, fibrous roots develop from the bottom of the basal plate. Soft and hard-coated bulblets are produced in the axils of the scale leaves.

1. Wild garlic

The wild garlic has 2 plant types: those that produce a scape (flowering stem) at the end of the growing season and those that do not. Plants that do not produce a scape are smaller and have fewer, more slender leaves. Plants that produce a scape typically have 2-4 leaves that appear circular and hollow in cross-section, and are much longer than the scape, at 15-60 centimeter long, 0.2-1 centimeter wide. They are easily flattened when young. Their bulbs are usually 1-2 centimeter long. They also have yellowish-brown outer coat with longitudinally parallel fibers, split into strips. Typically there are several hard-coated bulblets on stalks within the main bulb coats. Scapes 30-100 centimeter tall develop a few flowers and/or numerous grain-sized aerial bulbils. Bulbils are smooth, shiny parts, usually 5 mm in diameter. They often produce slender green leaves while still attached to the scape. Flower heads ~ 3 cm diameter. Flowers 3-4 millimeter long, greenish-white, pink, or reddish-purple, on stalks 1-1.5 centimeter long. Single bract short, deciduous, with a beak-like apex. Seeds flattened, semi-circular, ~ 3 millimeter long

2. Panicled onion

Plants typically have a mild onion odor however, they lack an odor when crushed. The panicled onion was introduced from Southern Europe probably as an ornamental plant. It has 3-5 leaves, narrowly channeled, less than or equal to the length of the scape, sheathing the lower 1/2 - 1/3 of the scape. panicled onion: Bulbs 1-1.5 cm long. Outer coat dark brown, with an obscure pattern. Inner coats light brown. Bulblets usually 1-3, about equal in size to the main bulb. Cut surface of a bulb quickly turns orange to dark red with exposure to air. Scapes 30-70 cm tall. Flower heads 3-7 cm diameter. Flowers 25-100, bell-shaped, 5-7 mm long, white to purplish-pink, on unequal stalks 1-4.5 cm long. Bracts 2, long-tapered, unequal. Longest bract 5-14 cm long, extends about 4-9 cm beyond the flowers. Seeds ovoid, ~ 4-6 mm long, 3-4 mm wide.

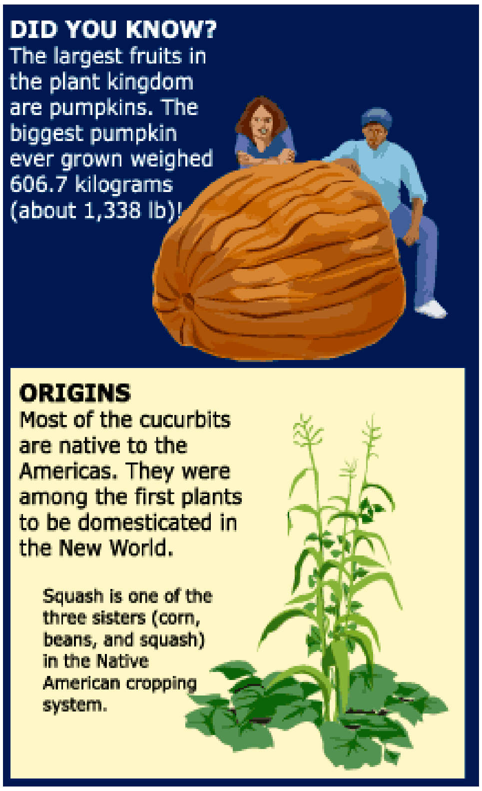
B. CRUCIFERAE FAMILY

The ***Cruciferae/Brassicaceae*** or Mustard Family is a large natural family of major economic importance containing a diverse variety of crop plants grown for salads, vegetables, condiments, and ornamental plants. There are two classifications for vegetable crops belonging to this family; the cole crops where the cabbage, cauliflower, heading broccoli, sprouting broccoli, kale, collard, mustard, Chinese cabbage, kohlrabi, and Brussels sprouts belong, and the root crops where turnip and radish belong.

This family of plants has a wide variety of economic uses, most importantly as a vegetable crop. Most cultivated edible varieties including Brussels sprouts, cabbage, broccoli, and cauliflower were developed by plant breeders from a single species, *Brassica oleracea.* Many crucifers are used as condiments and garnishes such as mustard and cress. Important crops are propagated from seed. Only minor crops such as watercress, horseradish and sea kale are vegetatively propagated. Although desired by the market in the case of crops such as mustard, radish and horseradish, crucifers may also be responsible for toxic manifestations when used as animal feed or in human nutrition. Recently, some cultivated varieties such as broccoli have been thought to help prevent cancer. Cruciferous oil seeds rank fifth in importance behind soybeans, cottonseeds, groundnut and sunflower seed. Animal feeds are provided by cruciferous crops in the form of silage, seed meal, forage crops (grazed in the field) and root fodder (used for winter feeds).

The Brassicaceae or Cruciferae Family contains both annual and perennial herbs but rarely small shrubs. Leaves are usually alternate, exstipulate, with unicellular, simple or branched hairs. The basic floral structure is highly characteristic and constant, containing four sepals, four petals, six stamen (four long and two short, a condition called tetradynamous), and an ovary with two parietal placenta. The form of the cruciferous flower unites the group more perhaps than any other character. This is always regular, perfect, and cruciform, especially for the cole crops such as broccoli. The older family name "Cruciferae" derives from the Maltese cross shape of the four petals. As in most of the crucifers, pollination is accomplished by nectar secretions into the bases of the pouched sepals which attracts insects and promotes cross-pollination; however, self-pollination of the flowers is a frequent occurrence.

C. CUCURBITACEAE FAMILY

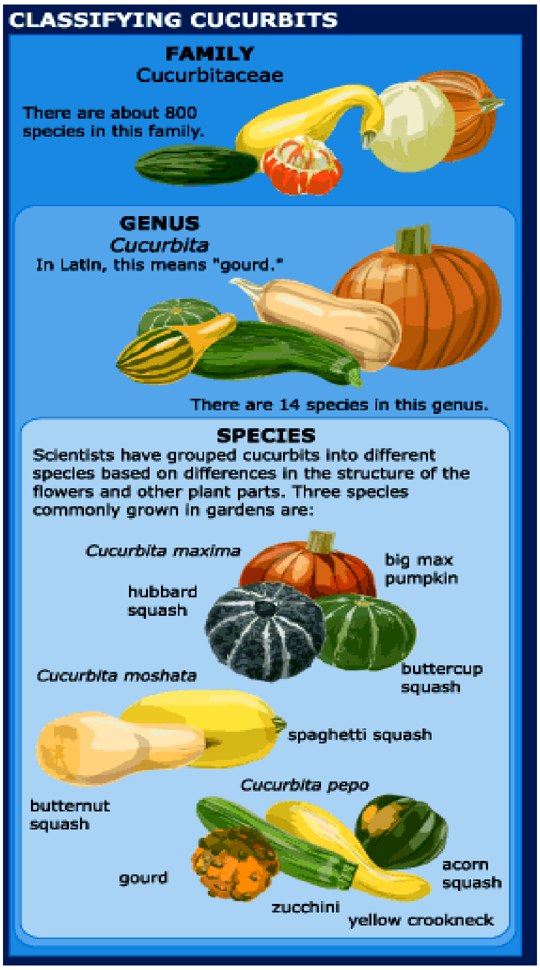


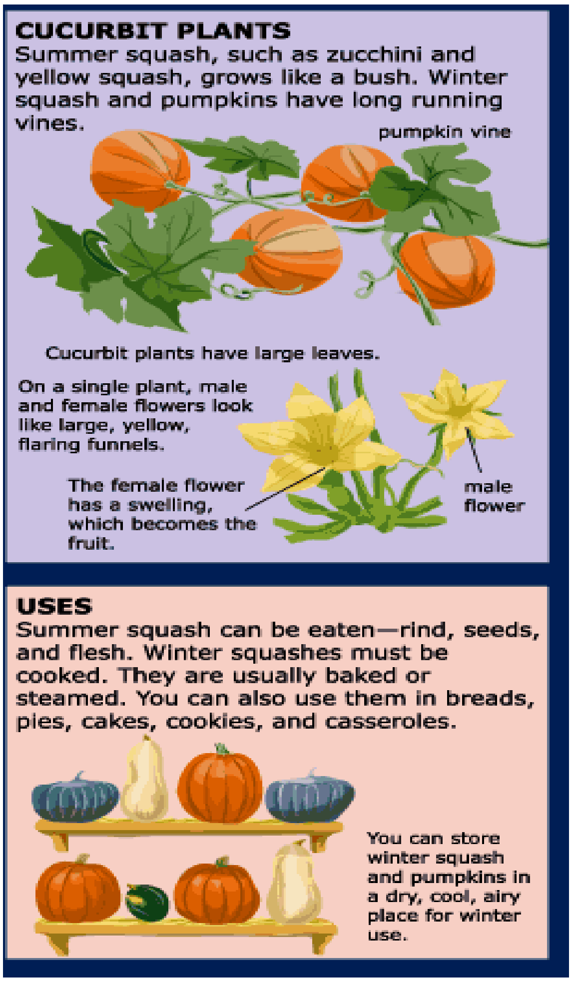
The Cucurbitaceae, commonly known as the gourd or melon family, includes a number of popular and important vegetables. The other crops of Cucurbitaceae are watermelon, summer squash, winter squash, and pumpkin. Among minor crops are citron, gherkin, and chayote. The last crop is propagated by large single-seeded fruits and is of no importance to the seed trade. The family is characterized briefly by the rather vigorous leafy prostrate vine habit, although some, notably the summer squash, have bush-type plants. The inflorescence and flowers, although distinct for each vegetable, are nevertheless similar to each other in color, general form, and arrangement of their parts.

The Cucurbitaceae are mostly prostrate or climbing herbaceous annuals comprising about 90 genera and 700 species that are further characterized by commonly having 5-angled stems and coiled tendrils. The leaves are alternate and usually palmately 5-

lobed or divided; stipules are absent. The flowers are actinomorphic and nearly always unisexual.

The perianth has a short to prolonged epigynous zone that bears a calyx of 3-6 segments or lobes and 3-6 petals or more frequently a 3-6-lobed sympetalous corolla. The androecium is highly variable, consisting of basically 5 distinct to completely connate stamens that frequently are twisted, folded or reduced in number. The gynoecium consists of a single compound pistil of 2-5 carpels, generally with one style and as many style branches or major stigma lobes as carpels, and an inferior ovary with one locule and usually numerous ovules on 2-5 parietal placentae or 3 locules with numerous ovules on axile placentae. The fruit is a type of berry called a pepo.





E. LEGUMINOUSAE FAMILY

Peas and the various bean crops are important vegetables in the family Leguminousae. Peas rank first and snap beans. The Leguminousae is distinguished by its unique flower in which self-pollination is the rule.

This is one of the largest and most useful plant families. - 17,000 species, distributed almost throughout the world. It includes many well-known vegetables particularly of temperate regions (Beans, Peas), ornamental trees in tropical regions (Bauhinia, Flamboyant, Cassia), fodder crops (Clover, Lucerne) and weeds (Vetches and Trefoils), and their growth habits vary from ground cover and aquatic to shrubs, climbers and trees. Many species of trees in this family are important for their timber.

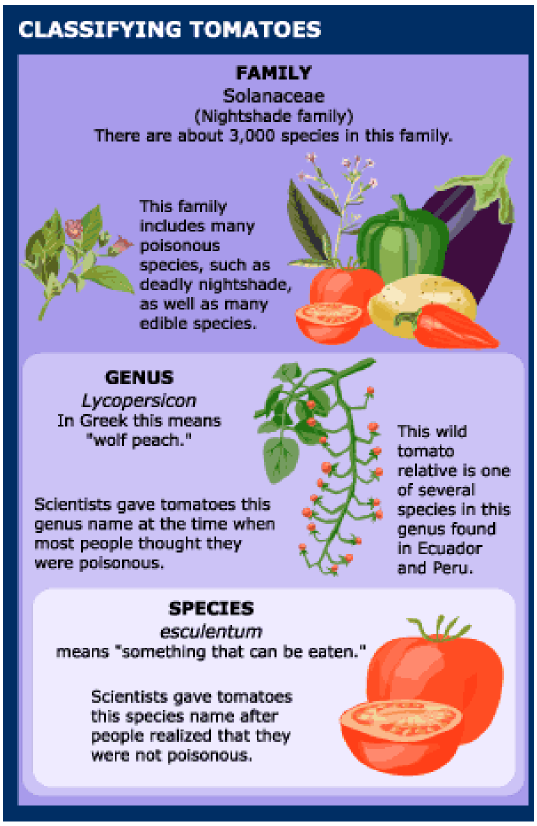
Leaves composite, seldom single, with very conspicuous stipules, in many cases ending in tendrils or filaments**.** Sometimes leaves are reduced to spines. Flowers in raceme, Calyx: 5 joined sepals, Corolla: 5 petals (One at the top, called standard; two sided ones, called wings and two joined ones below which form the keel)

The leaves of this plant family are placed alternately up the stem, and are pinnate or bipinnate. In some species, the leaves are able to close together at night (nyctinasty), and in some species of Mimosa they close when touched. The roots are one of the most easily recognizable features of this plant family. Most species have irregular nodules on the roots which enable the plant to absorb nitrogen from the air in the soil and convert it into the nitrogen the plant needs for growth. This enables the species to grow and produce crops in poor soil.

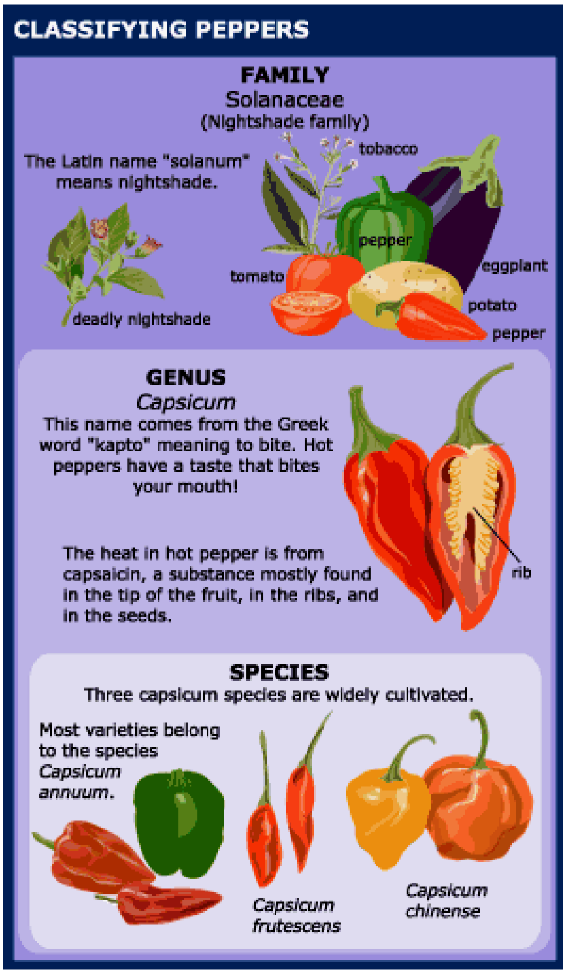
Many members of the Leguminosae family have flowers of the typical 'pea' type. These are composed of one large back petal (the standard), two side petals called wings and two lower petals fused together to form a 'keel'. In members of the family which have other flower shapes, there are still five petals. The flowers may occur individually, or in large clusters.

It is the seedpods that give this family its original name. The typical pea-pod shape is a legume. It is always a single chamber, although it may be constricted between the individual seeds. The pod may contain just one or several seeds, and they are usually large, and sometimes brightly colored. The coat of the individual seed is often watertight. Each seed contains a large embryo and little endosperm, so they often germinate quickly once the seed coat is punctured.

F. SOLANACEAE FAMILY



The seed-plants (Spermatophytae) also called Anthophyta, have as a general characteristic: seed-bearing flowering plants. The seeds are contained in an ovarium, so the pollen-grains cannot come to the ovules directly, but fertilization takes place via the style (Angiospermae). The development of the embryo is by the two cotyledons (Dicotyledoneae). There is a long-living root and the transport-vessels are arranged into a circle. The leaves do have distinct petioles, are net-veined (Reticulatovenosus) and often have small supporting leaflets. Pollination is simultaneous. The perianth is lobbed but grown together to some extend in calyx and corolla (sepals and petals respectively). Flowers mostly dorsi-ventralis with connate filaments, regularly symmetrical, gamopetalous, five numbered (seldom 3-10 sepals and seldom 10 petals). The leaves are placed alternately, solitary and sometimes have deep incisions. In the vicinity of the flower the leaves are more opposite but not completely so. The fruit is a dry capsule or a berry. There is only one style and the stigma is two-lobbed. The plants are herbs or shrubs, small trees or climbers. There are prickles in a lot of the species or at least they are covered with hairs.



Source:

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PART IX: WEEDS AND WEED MANAGEMENT

- Reduce rice yields by competing with the rice plants for sunlight, moisture, and soil nutrients.
- Fertilizer application may not increase yields in weedy fields because weeds absorb nitrogen more effectively than the rice plants do.
- Weeds are also harmful because they may be alternate hosts for insect and disease pests of rice. They may also provide shelter for rats.

A. Types of Weeds

Weeds can be divided into three general types, based on their appearance:

1. Grasses
   - Long narrow leaves
   - Parallel veins
   - Round hollow stem
   - Leaves are aligned up and down the stem in 2 rows

2. Sedges – similar to grasses but-
   - Leaves are aligned up and down the stem in 3 rows.
   - Stems are usually solid and triangular.

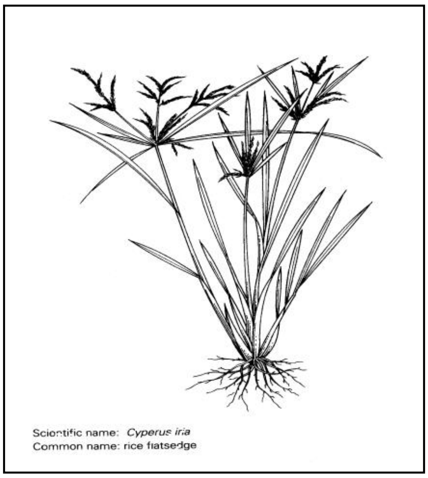
3. Broadleaf Weeds
   - Leaves may have various shapes and arrangements of veins.
   - Leaves are usually wider than those of grasses and sedges.

Weeds are also sometimes grouped according to the length of their life cycle:

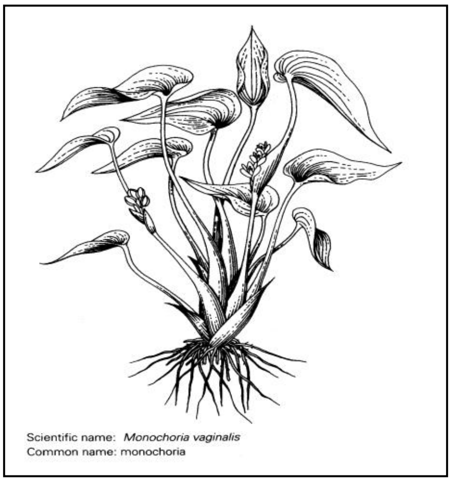
- Perennials require more than a year to complete their life cycle.
- Annuals complete their life cycle in 1 year.

Common Grass

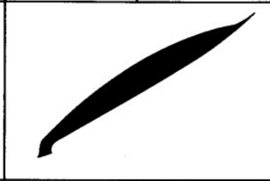
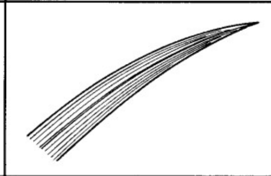
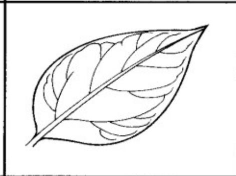
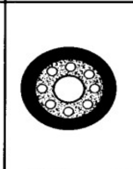
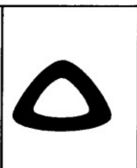
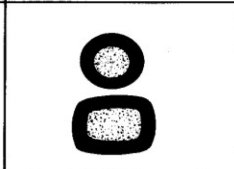
Common Sedge



Common Broadleaf



Differences among Grasses, Sedges, and Broad-Leaved Weeds

Character	Grasses	Sedges	Broad-leaved weeds
Leaf shape			
Vein arrangement			
Stem cross-section			
Plant shape			
Example	*Echinochloa*	*Cyperus*	*Monochoria*

B. Control of Weeds

Methods

1. *Control by Hand Pulling*

    - Pulling weeds by hand is a manual method of control.
    - Hand pulling takes a lot of time.

2. *Control by Mechanical Means*

    - A rotary weeder is more efficient than hand weeding.
    - Straight row planting is necessary when using a rotary weeder.
    - Drain standing water from the field when using a rotary weeder.

3. *Control by Water Management*

    - Most grasses and sedges will not grow when covered with 5-10 cm of water.
    - Flooding will not control some broad-leaved weeds.
    - Many weed seeds do not germinate under water.

4. *Control by Land Preparation*

   - Weeds can grow better than rice when land is poorly and unevenly prepared and some areas are not covered by water.

5. *Control by Crop Competition*

   - The closer the plant spacing, the fewer the weeds because there is less light for the weeds to germinate and grow in.
   - The shorter the weeds, the less weed damage.

6. *Control by Herbicides*

Sources:

Reissig, W.H. et. al. Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia. International Rice Research Institute. Los Baños, Laguna, Philippines. 273-276pp.
Vergara, B.S. 1992. A Farmer's Primer on Growing Rice. International Rice Research Institute. Los Baños, Laguna, Philippines. 128-143 pp.

PART X: PESTICIDE HAZARDS

PESTICIDES

Pesticide is a broad term that describes all products used to control insects, diseases, weeds, fungi and other "pests" on plants, fruits, vegetables, animals and in buildings.

Pesticide used in crop production has been suspected of being a major contributor to environmental pollution. The post-war period has seen continued increases in both agricultural productivity and pesticide use. There are widespread and growing concerns of pesticide over-use, relating to a number of dimensions such as contamination of ground water, surface water, soils and food, and the consequent impacts on wildlife and human health. The use and abuse of pesticides have disturbed the ecological balance between pests and their predators in developed and developing countries. The lesser developed countries still do not use as much pesticide as does the industrialized world, however pesticide use in many third world countries is not as regulated as it is in the developed countries.

There are a number of hazards that are associated with exposure to pesticides. Persons applying and handling the pesticide, because they have the potential to come in contact with concentrated formulations, are at greatest risk of harm. The only way to reduce this risk is to avoid the use of pesticides.

A. Pesticide Formulations

A pesticide is not usually applied in pure form. It must be diluted with water, oil or an active solid so it is less toxic to humans and can be spread evenly over a large area. The final product is called a pesticide formulation. These formulations include:

1. *Dusts*. These require no mixing and can be applied directly to the plant. However, dusts may drift from where they are applied and contaminate areas where humans and livestocks live.
2. *Granules*. These can be applied as bought with simple equipment and require no additional mixing. Granules do not easily drift to other areas.
3. *Liquid formulations* (LFs). These are also called emulsifiable. Samples of LFs are:
    a. *Concentrates* (Ecs) and are mixed with water and sprayed. They contain a high concentration of pesticides and are easy to transport and store. They are effective for treating foliage and require little agitation in the tank to have them mixed.
    b. *Flowables* (LFs). These are special kind of LFs in which finely ground solid particles of pesticides are suspended in a liquid. They are applied and used in the same way as other LFs.
    c. *Wettable Powders* (WPs). These have the same kind of materials as Ecs except that the insecticide is in small, dry, powderlike particles. WPs are

mixed with water to form suspensions and has to be agitated during application.

d. *Soluble Powders* (SPs). These have the same materials as the WPs but are dissolved in water to form solutions. Thus, they do not settle down like the WPs.
e. *Poisonous Baits* (PBs). Poisonous bait are food or other substances with which pesticides are mixed. Pests eat the bait and die.

B. Effects of Indiscriminate Use of Pesticides

- Health impairment due to direct or indirect exposure to hazardous chemicals
- Contamination of ground and surface water through run-off, seepage and percolation
- Pesticide residue through the food chain to the farm family and urban consumers
- An increase in the resistance of pest populations to pesticides.
- Reduction of beneficial organisms
- Pesticides are useful component of pest management in vegetables but these must be used only when necessary and be applied properly. Improper use may cause the following side effects:

1. *Environment pollution*. Some pesticides may be taken in from the environment and accumulated in animals and plants. Wildlife and people who eat meat contaminated with pesticides may be poisoned even without direct contact with a pesticide. This type of pesticide is very harmful to the environment and causes long-lasting damage.
2. *Phytotoxicity*. The active ingredient (ai) or materials in pesticide formulations may damage crop plant. Phytotoxicity or toxicity to plant may be caused by:

   a. Using the wrong pesticide
   b. Applying an inappropriate pesticide mixture
   c. Wrong timing of application
   d. Using too much pesticide
   e. Selecting the wrong pesticide formulation

3. *Damage to non-target organism*. If pesticides are carried by wind, water or other means from the area where they are applied, they may be harmful to friendly insects and microorganisms, humans, livestock, wildlife, and crops.

C. Steps to Consider Before Choosing and Applying Pesticide

a. Identify the pest. Carefully check the field to determine both symptoms or sign of damage and species of pests
b. Consider other control methods. After identifying the pest, determine if control is necessary, consider other control measures, and decide on the most appropriate one for implementation.
c. Choose a pesticide that is effective against the target pest; has directions on the label; will not cause injury to the crop; and is least harmful to beneficials (parasitoids and predators).

d. If possible, choose pesticides with color bands; blue (moderately toxic) and green (slightly toxic) in the label rather than yellow (highly toxic) and red (extremely toxic) bands.

D. Precautions in Handling Pesticides

A. Before application

1. Read the label to determine:
    a. Target organism
    b. Rate and time of application
    c. Need for protective clothing and equipment
    d. Antidotes and other safety measures
    e. Field reentry intervals after treatment

2. Check the Sprayer

    a. Fill the tank with plain water and test the sprayer to be sure that there are no leaks or loose connections and the equipment is working properly.
    b. Repair or replace any worn-out faulty part.

3. Mixing and filling.

    Extra precaution is necessary when mixing and filling sprayers because pesticides are concentrated.

    a. Wear protective clothing.
    b. Open pesticide container carefully to avoid splashes, spills, or drifts.
    c. Stand upwind when adding materials to the sprayer to avoid drift of pesticides fumes or particles.
    d. Keep your head away from the opening of the sprayer.
    e. Wash and change clothes immediately if pesticide is spilled on clothing.
    f. Do not use bare hands in mixing pesticides, nor allow concentrated materials to touch bare skin.

B. During Application

1. Wear protective clothing
2. Do not eat, drink, smoke, or blow clogged nozzles, with your mouth while applying pesticides.
3. Do not apply when it is windy to avoid pesticide drift.
4. Do not spray near or in ponds, lakes or streams.
5. Spray areas near homes in early mornings or evenings when humans, pets, and livestock are less likely to be exposed.

C. After Application

1. Make sure the sprayer is empty. Clean and rinse the sprayer inside and out and return it to storage area. Dispose of empty pesticide containers properly.
2. Store remaining pesticides properly.
3. Bathe and change clothing after application of pesticides.
4. Stay away from treated field for 1-2 days. This prevents poisoning through contact with treated plants, or inhalation of pesticide fumes.

E. Types of Pesticide Poisoning and Their Symptoms

A. There are two different kinds of poisoning. These are acute and chronic.

1. *Acute poisoning* occurs after exposure to just a single dose of pesticide. Symptoms may occur immediately or be slightly delayed.
2. *Chronic poisoning* occurs after repeated exposures over a long period of time. Symptoms include nervousness, slowed reflexes, irritability, and a general decline of health.

B. The general symptoms of poisoning include:

1. Mild poisoning or early symptom of acute poisoning:

   a. Irritation of eyes, nose, or throat
   b. Headache and/or dizziness
   c. Fatigue and/or diarrhea

2. Moderate poisoning or early symptoms of acute poisoning:

   a. Upset stomach
   b. Extreme weakness, excessive perspiration;
   c. Muscle twitches, rapid heartbeat

3. Severe or acute poisoning:

   a. Vomiting and convulsions, pinpoint pupils
   b. Difficulty in breathing, unconsciousness

F. First aid measures for pesticide poisoning

A. Call a doctor or bring the patient to the hospital. Show the pesticide and/or label to the doctor.

B. While waiting for medical help or while transporting the victim to the hospital, apply the following first aid measures:

1. If the patient has pesticide on the skin, wash it off quickly to lessen the degree of injury.

a. Remove the patient's clothing.
b. Drench his/her skin and body with water.
c. Dry the patient and wrap him/her in a clean blanket.

2. If the patient has poison in the eye, wash the eye immediately and as gently as possible.

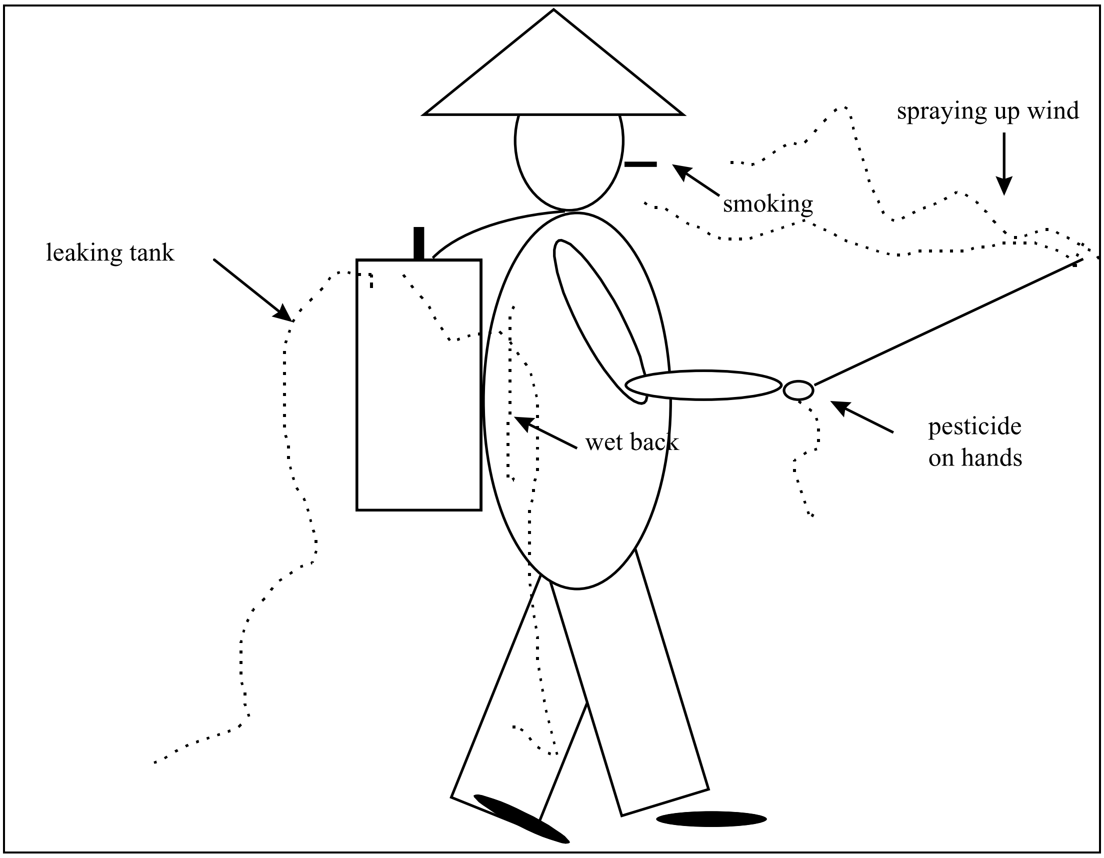
a. Hold the eyelids open and wash the eyes with a gentle stream of running water for 15 minutes or more.
b. Do not use chemicals in the wash water.

3. If the patient has inhaled poison, immediately move him/her to fresh air.

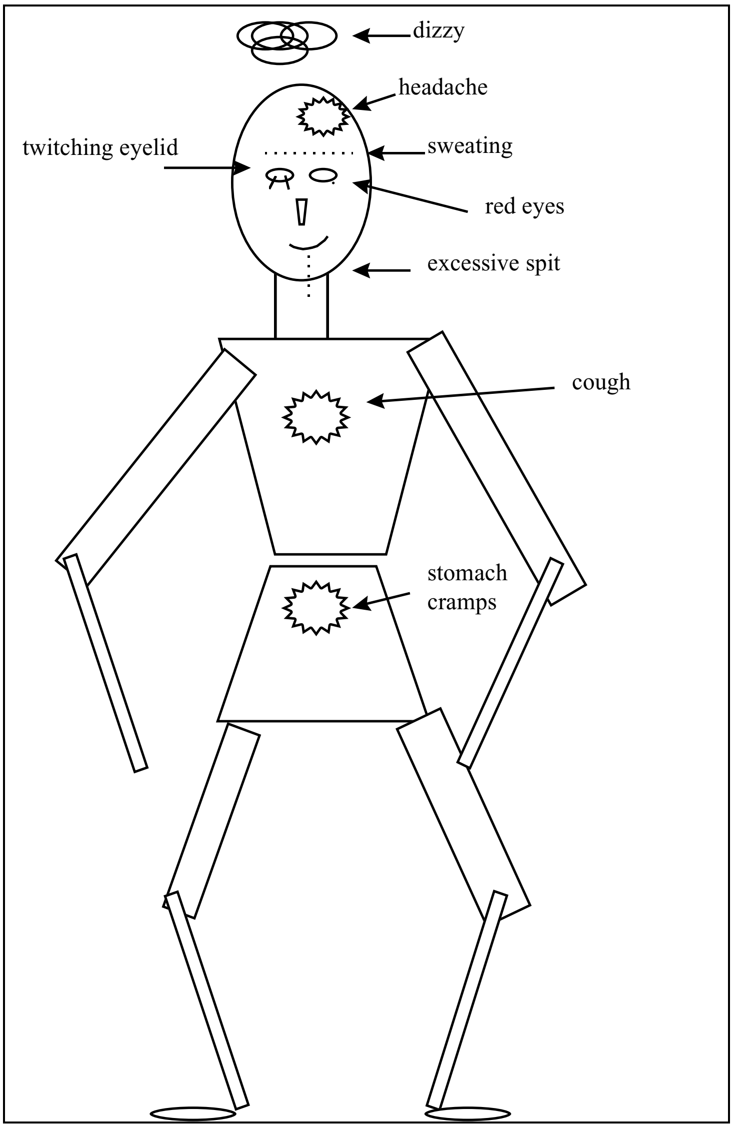
a. Loosen all his/her tight clothing, prevent chilling.
b. Apply artificial respiration if breathing stops or is irregular.
c. Do not give/her alcohol in any form.

G. Proper Storage and Disposal of Pesticides

A. Store pesticides in their original containers and keep them in safe, dry, locked, and well-ventilated area.
B. They must be sealed, labeled correctly, and kept out of the reach of children and animals.



Exposure during spraying



Signs or Symptoms of Pesticide Poisoning

Source:
http://www.communityipm.org

PART XI: POST HARVEST PROCESSING OF VEGETABLES

A. Harvest and Handling Considerations

Besides the initial capital investment in the greenhouse structure for crop production, thought must be given to the requirements for proper harvesting, packing, and shipping. Each of these operations are interrelated, and must work together smoothly to maintain quality for maximum postharvest life. Specific postharvest operations depend on the particular greenhouse facility and on the number and types of crops grown. The principal considerations for these components are outlined below.

Maintaining Quality

The primary goal of harvest and postharvest handling is to maintain vegetable quality as close as possible to harvest condition through subsequent handling operations. Maintaining high quality is the thread that links each of the components in the harvest/handling system, and carelessness at any stage can quickly change the grade. Typical quality parameters include color, firmness, size, shape, flavor, aroma and freedom from injury and disease.

Vegetable quality is most often reduced by two factors: mechanical injury and poor temperature management. Mechanical injuries include cuts, abrasions, and punctures incurred during harvest and handling operations, and bruises caused by drops or overfilled containers. These injuries provide entry points for decay organisms and reduce storage life. Proper temperature management involves the rapid removal of field heat shortly after harvest to the optimal storage temperature (known as rapid cooling, or precooling). Once cooled, the product should be kept at that temperature, usually with high relative humidity, during subsequent handling and storage.

1. <u>Harvest Operations</u>

Crops must be harvested at the optimal maturity for the intended use. Proper harvesting techniques are also essential for minimizing mechanical injury. Frequent sanitizing of hands/gloves and clippers can assist in reducing damage and disease. A reusable picking container that has smooth inner surfaces, is not too deep and is made of an easily cleanable material, like plastic must be selected. After harvest, the product should be protected from the sun to prevent temperature increase. Provision should also be made for gently transporting the harvested product to the packing/storage area. Prior to reuse, the containers should be cleansed and sanitized to minimize the spread of decay pathogens.

Optimal Harvest Factors

Vegetable crops comprise a wide range of plant structures and organs, such as roots (carrots), tubers (potatoes), leaves (lettuce), stalks (celery), immature fruits (cucumbers and peppers), and mature fruits (tomatoes). In order to maximize storage life, crops must be harvested at the appropriate stage of growth, or maturity.

There is a distinction between maturity and ripeness. Horticultural maturity is defined as "the stage of development when a plant or plant part possesses the prerequisites for utilization by consumers for a particular purpose" (Watada, et al., 1984). Cucumbers, lettuce, and peppers are harvested at various stages (horticultural maturity) prior to reaching physiological maturity, or completion of the growth phase. Ripening is a process that occurs in fruits after they have reached physiological maturity. Changes in the postharvest color, texture, and flavor of tomatoes occur during the ripening phase.

Leaf lettuce is harvested when the leaves are of typical color for the lettuce type being grown, not wilted, and free from defects such as tipburn. The entire plants can be harvested and placed directly into individual plastic sleeves or containers. Roots should be rinsed free of any soil, media, etc. By keeping the roots moist, wilting will be minimized during subsequent handling. The roots can also be trimmed partially or entirely at harvest. Cucumbers should be picked without stems at the appropriate developmental stage; peppers and tomatoes should be picked with stems attached.

Cucumbers and peppers require frequent, multiple harvests in order to supply a uniformly mature product with optimal quality to the desired market.

Tomatoes are also harvested in multiple harvests when there is some color showing on the fruit surface, usually the breaker (less than 10% color) or turning (10 to 30% color) stages. Multiple harvests necessitate attentiveness on the part of the greenhouse manager and a reliable supply of labor.

Harvesting should be done during the early morning hours to avoid accumulation of additional "field heat." Proper harvesting techniques must also be used to minimize injury. Workers should closely trim fingernails to reduce punctures. Peppers should be grasped so that they are detached with the stems intact. At harvest, the crops should be carefully placed in single or double layer containers to avoid bruising. Once filled with the harvested crop, the containers should be quickly, but carefully, transported to the packing shed to reduce mechanical injuries, such as bruises, abrasions, and cuts. Injuries provide sites for decay infection later during handling and marketing. Harvested vegetables should never be held in direct sunlight which leads to further fruit warming, wilting, or sunscald. For best protection during handling and shipping, these crops should be finally packed in single-layer containers. Fruits should be free of soil, waterspots, etc., and may require washing prior to packing. Containers should be selected for adequate strength to withstand stacking and shipping. Ventilation holes should be present (about 5% of the exposed surface area of the carton) to ensure sufficient air circulation during storage and shipping.

Tomatoes are typically placed stemdown. However, tomatoes shipped in this manner will develop flat spots on the shoulders as the fruits ripen and soften. Cucumbers are quite susceptible to water loss. Plastic film wraps, shrinkor wax can be applied to individual cucumbers to reduce shriveling. As mentioned, lettuce can be placed in plastic bags to reduce wilting.

After packing, the containers should be stacked on pallets. By unitizing the containers, subsequent handling operations are greatly facilitated, saving labor costs and reducing mechanical injury which can occur with repeated handling. The stacked containers should be secured on the pallet with strapping, netting, or glue to avoid shifting during handling.

2. Storage

For optimum quality retention during shipping and retailing, these vegetables should be cooled as quickly as possible after harvest and packing. Precooling involves procedures which rapidly cool the crop and, therefore, lower the metabolism rate which slows ripening, retards development of decay, and reduces wilting. Volume 2 of this handbook describes precooling procedures in greater detail. Cucumbers and peppers should be cooled to 50°F (10°C). Tomatoes which are at the breaker or turning stage should not be cooled below 55°F (12°C), while tomatoes at pink to light red ripeness stages may be stored successfully at 50°F (10°C). Holding these vegetables at temperatures which are lower than recommended temperatures during precooling or during refrigerated storage or transport can cause chilling injury. Chilling injury is expressed by such symptoms as dark, sunken lesions on the vegetable surface, abnormal color development, and increased susceptibility to decay. It is time/temperature related; in other words, the longer the product is held below the recommended storage temperature, the greater the extent of chilling injury. Although lettuce is not chilling sensitive, it should not be cooled less than 33°F (1°C) to avoid freezing.

All horticultural crops are sensitive to ethylene gas, a naturally occurring plant hormone. However, crops have varied responses to ethylene. Many crops undergo a distinct ripening phase which is characterized by production of relatively large amounts of ethylene. Tomato is an example of this type of crop. Exposure to ethylene can be detrimental to nonethylene producing crops being stored in the same cold room or transported in the same refrigerated trailer with ethylene crops. Lettuce, for example, will develop russet spots when exposed to as little as 1 part per million of ethylene. Peppers and cucumbers will also deteriorate more rapidly when exposed to ethylene as evidenced by loss of green color (yellowing), texture, and flavor (Ryall and Lipton, 1979). Therefore, tomatoes should be held in a separate cold room when these other crops are being stored. Ethylene is also produced from combustion. Exhaust from unit heaters, fork lifts, vehicles, and cigarettes can accumulate in cold rooms and cause injury to the crop. A convenient list of vegetables which are compatible and incompatible for storage shipping is available (Sherman, 1985).

3. Sanitation

Development of decay during shipping is a major cause of postharvest loss. Decay can be markedly reduced by a routine sanitation program. Such a program should include prompt removal of trash, plant cuttings, diseased plant parts, and culls from the greenhouse, picking containers, packing shed, precooler, and cold room. Whenever water contacts the crop, chlorine should be added at a rate of 100 to 150 parts per million

(Hicks and Segall, undated; Sherman et al., undated). Picking containers, packing line components, and cold room floors and walls should be cleaned periodically with chlorine solution to reduce populations of decay organisms. Local environmental regulatory agencies should be consulted for appropriate disposal of packing shed wash water and culls.

Consistently high quality vegetables can be produced and marketed by greenhouse operations if there is first a thorough understanding of the biological requirements of the crop for optimal storage life. Then, appropriate harvest and handling techniques can be employed for each crop which will include conscientious attention to maturity indices and grade standards, care in handling, proper packaging, timeliness and thoroughness in precooling, storage at the desired temperature and relative humidity, and implementation of a sanitation program.

Sources:

http://edis.ifas.ufl.edu/CV249
http://edis.ifas.ufl.edu/CV269

PART VI: PRODUCTION OF SELECTED VEGETABLE CROPS

A. ALLIUM FAMILY

1. <u>ONIONS</u>

a. Introduction

Onions are group of monocotyledonous plants botanically known as *Allium cepa L* It is a biennial herb usually grown as an annual from bulbs. The bulb is composed of concentric, fleshy, enlarged leaf bases or scales. The outer leaf bases lose moisture and become scaly and the inner leaves generally thicken as bulbs develop. The green leaves above the bulb are hallow and arise sequentially from the meristem at the innermost point at the base of the bulb. The stem is very small and insignificant during vegetative growth. The fruit is globular capsule with up to 6 seeds. The seed measures 6 mm x 4 mm, black and wrinkled.

Two large groups are now considered in onion: Group Common Onion and the Group Aggregatum. The former has large bulbs, normally single, reproduced by seeds or from seed-grown bulbils (sets) while the latter has smaller bulbs forming several aggregated cluster, and they reproduce vegetatively through the lateral bulbs (daughter bulbs).

b. Climate and soil requirement

Places with distinct wet and dry season are suitable for commercial onion production. Onion grows best in a mild climate with no heat and rainfall. A temperature of 18 to 20 ºC and ample moisture are ideal during early stages of growth. For bulbing, temperature of 21 to 27 ºC is favorable. Dry and warm conditions are necessary for proper maturation of bulbs.

Although onion grows in many types of soil, it grows best in well drained sandy loam and silty loam soil which are friable, fertile and can maintain adequate moisture. A soil pH of 5.8 to 7.00 is needed for the plant to exhibit its good growth.

Onions are herbs known for their pungency. Because of this, they are one of the most indispensable culinary ingredients in the world. Generally, they are used in salads, pickles, cooking, and frying. Grind onions can be mixed with other ingredients for used as spice for meat and fish. Onion also plays an important role in traditional medicine and in suppressing the blood sugar level and platelet aggregation.

Table 7. Varieties of Onions

Variety	Maturity
Red Pinoy	90 – 95 DAT
Neuventa	60 – 70 DAT
Red Viking	90 – 95 DAT
Niagara	90 – 95 DAT
Kaneko	90 – 95 DAT
Rio Colorado	90 – 95 DAT
Robins	90 – 100 DAT
Maagap	60 DAT
Batanes	90 DAT
Tanduyong	90 DAT
Niagara Yellow	90 – 100 DAS
Kaneko Yellow	90 – 100 DAS

Table 8. Growth stages of Onions

Growth Stages	No. of Days
Seedling	30 – 45 DAS
Recovery	3 – 7 DAT
Vegetative/juvenile	25 – 30 DAT
Bulb formation	30 – 60 DAT
Maturity/Harvest	60 – 95 DAT

c. Seeding

The seedbed for onion is from 50 – 70 cm wide, elevated, at any convenient length. The number of seedbed depends on the size of the area to be planted.

Plow the seedbed area as deep as possible (6 – 8cm) and then harrow several times. To raise the seedbed (20 – 30cm high), excavate the soil in the proposed pathways and put it on the proposed seedbed. The pathway shall serve as irrigation and drainage canal. Pulverize the topsoil and level the surface using hand tools like rake. You may incorporate organic fertilizer.

Make shallow furrows (about 1 cm deep) horizontally across the seedbed at a spacing of 2-5cm between furrows. Put complete fertilizer (14-14-14) into the furrows and cover with fine soil. Sow the seeds at the rate of 200 – 250 seeds per 5 meter long at a depth twice the seed size. About 5-6 kg of seeds are needed per hectare. Cover the seeds with organic fertilizer. Put rice straw as mulch on top of the seedbed. Water the seedbed thoroughly.

For Tanduyong or multiplier, the bulblets are planted in the seedbed 2-3 cm away from each other in the row. The rows are spaced 3-5 cm. Each bulblet is expected to produce from 5 to 10 seedlings which are separated during planting. About 150 – 200 kg of good bulblets are needed per hectare.

d. Land preparation

The area is plowed and harrowed several times to provide good soil tilth and to reduce the weed population significantly before planting.

First plowing must be deep enough to uproot all the standing weeds. Harrow the soil and collect all uprooted weeds. Irrigate the area to allow the weed seeds to germinate. One to two weeks after germination, plow and harrow again. Repeat the whole process once more.

For final land preparation, the area is plowed once and harrowed several times to pulverized soil. Levelling follows. Prepare the beds for transplanting at a desired size and distance from each bed.

e. Planting

By using the pointed end of a dibble (20-25 cm long rounded stick), shallow holes are made in the mulched or unmulched plot enough to accommodate the root and the surface of the base of the seedling (root plate). The lower part of the seedling is gently inserted into the shallow hole and then the soil is pressed for better contact between the soil and the roots. The ideal distance of planting is 6 x 10 cm for multiplier and 8 x 12 cm for bulb onion.

In the direct seeding, 3 to 5 seeds are planted per hill at a distance of 8-15 between hills in the furrow. After planting, the seeds are covered with fine soil or organic matter.

f. Fertilization

When the seedlings have recovered from transplanting shock, apply 150 kgs of urea and 100 kg of muriate of potash per hectare. Repeat the application when the bulbs start to develop. Refer to soil analysis for proper fertilizer recommendations. The fertilizer material can be broadcasted or dissolved in solution.

g. Irrigation

Initial watering is done immediately after planting. In the unmulched plot, watering is done frequently especially during the early stages of vegetative growth and early bulbing stage. Watering should be done in the morning to avoid incidence of diseases. For mulched plot, watering can be done 5-7 days or when need arises as shown by temporary wilting.

h. Pest and Diseases

Common cutworm, armyworm and leaf miner often attack onion throughout its entire life cycle. Cutworm is the major pest of onion not only because of its polyphagous in nature but also to high multiplication especially during dry season. Thrips also infest the crop at warm weather.

Disease is more serious problem in onion production rather than insect pest. Different types of diseases infect the onion from seedling up to the storage which greatly reduces profit.

Damping off at seedling stage and purple blotch at plantation are the most serious problem of onion. Other problems occur during its growing period are Stemphylium, downy mildew, botrytis leaf blight, cercospora leaf spot, basal plate rot and pink root disease.

i. Weeding

Weeds are serious problem in onion production. Yield decreases with increasing population of weeds. A weed-free condition must be observed during the first 30-45 days after transplanting or 45-60 days after seeding. Hand-pull the weeds as they appear or use selective herbicide

j. Harvesting

Softening of neck, color change of the leaves from green to yellow, falling over of tops and death of roots are manifestation of maturity, signs that the onions are ready to harvest. Onion is a shallow-rooted plant and usually only the roots are in contact with the soil. It is best to use hand tools like trowel or dibble to uproot the plant in order to minimize damage. Selective harvesting is suggested to avoid rapid deterioration of immature bulbs in a lot that may enhance the deterioration or more matured bulbs.

2. GARLIC

a. Introduction

Garlic (*Allium sativum*) is an erect herb, up to 60 cm tall, grown as an annual from small bulbs called cloves. The roots are adventitious and superficial. The bulb is depressed globular to avoid lateral cloves that developed from axillary buds of younger leaves. Each clove is enclosed with sheath. Real stem is very short, flattened, forming a disk at the base of the bulb. Leaves are distichous, glabrous, linear oblong, often V-shaped in section. Fruits are aborted and without seeds.

b. Climate and soil requirements

Garlic grows well in easily drained clay or sandy loam soils with pH of 5.5 to 6.5. It requires type 1 climate (dry from November to April**).** Garlic grows best under moderate temperature and rainfall. For bulbing to occur, a long photoperiod is needed.

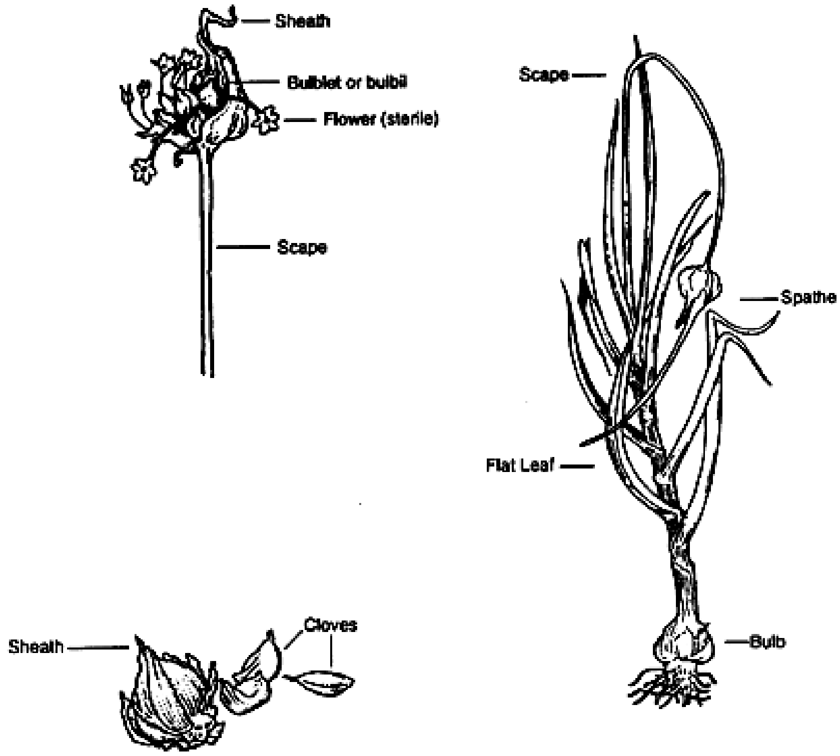
Table 9. Varieties of Garlic

Variety	Maturity (DAP)
Nueva Ecija pink	120
Ilocos Pink	124
Ilocos white	124
Tan Bolters	105 - 120
Batanes white	120
Batangas white	120
Batangas purple	120

Table 10. Growth Stages of Garlic

Growth Stage	Maturity Days After Planting (DAP)
Seeding	30 DAP
Vegetative	55 – 60 DAP
Bulbing	60 – 90 DAP
Maturity	90 - 120 DAP
Harvesting	120 DAP

<u>Garlic Plant Parts</u>



c. Preparation of planting materials

Select fully matured, well developed bulbs immediately after harvest. Get large cloves that are free from pests and mechanical damage. A hectare needs 700 kg of planting materials.

d. Land preparation

There are two ways on how to plant garlic, zero tillage and conventional plowing. Conventional plowing needs to plow the field 10 cm deep and then harrowed until good tilt is attained. Make raised beds 7 to 8 cm high. This method is recommended for early planting especially when the field is not easily drained. In zero tillage, immediately after harvesting palay, stubbles and weeds are cut close to the ground and their roots scraped off. The field is leveled. Rice straw is spread all over the field to about 5 cm thick and flooded overnight. In 3 to 5 days the field is ready for use.

e. Planting

Usually, planting of garlic is done after rainy season or before dry season (October – January). The clove is planted with the aid of a pointed stick or dibble. The clove is inserted down the hole vertically. The depth is 1 to 2 cm. Distance of planting is 12 – 15 x 20cm. After planting, the soil is pressed gently to permit a good clove-soil contact.

f. Fertilization

The total amount of P and K and half of N is applied at planting time or a few weeks after N is sidedressed at bulbing stage. For best results, the fertilizer should be applied in band 5-8 cm below the seeds.

g. Irrigation

Irrigate the field by flooding or overhead or both depending on the source of irrigation. Irrigate the crop at 2-3 weeks interval depending on soil moisture and crop appearance.

Irrigation should be stopped as the crop approaches maturity so that the field is dry for harvesting. It will also prevent rotting of the roots and bulbs.

h. Weeding

Good weed control is essential in garlic production. Alliums are poor competitors; weeds can cut garlic yields in half, and lower the quality of the crop.

Garlic is usually mulched so that weeding is rarely necessary. Eliminate weeds during early growth stages of the crop to avoid competition.

i. Harvesting

Garlic plants are ready for harvest at 110 – 120 days after planting (DAP) or when the leaves turn yellow and dry. Maturity is indicated by the softening of the neck or part of the stem just above the bulb. Harvest manually by uprooting the matured plant.

j. Drying

Before storage, trim the shoots of the bulbs sparingly with a curve-bladed shear and then grade the bulbs. Sun dry the harvested bulbs for 7 to 10 days by spreading on concrete pavement. Avoid sunscalding by covering each layer of bulbs with another layer of bulbs. Place an orderly and overlay of dried lagundi leaves, *Vitex negundo* (Dangla) while the bulbs are being dried at the start of storage to reduce damage by the cigarette beetle.

B. CRUCIFERAE FAMILY

1. CABBAGE

a. Introduction

Cabbage, Brassica oleraceae var. capitata, is a member of the family cruciferae. Similar to other vegetables, cabbage is not indigenous to Asia. It originates in Western Europe, with temperate climates. Common cabbage is an excellent source of calcium and vitamin A and C. It is a short duration vegetable crop that may be grown both in lowland and highland areas from October to January.

b. Climate and soil requirement

Cabbage can be grown in lowland and upland areas. In lowland areas, raised beds are required during wet season with sandy or clay loam textured soils.

For best yields, the best planting season is during October to January, although cabbage can be grown all year round.

Table 11. Varieties of Cabbage

Variety	Maturity (DAT)
Cabuko F1	70
Apo verde	55 – 60
KK cross	55 – 60
KY cross	55 – 60
Scorpio	80
Rareball globe	55 – 60
Ring	55 – 60
Green express	55 – 60
Marion market	55 – 60
Copenhagen	55 – 60
Wakamini	55 - 60

Table 12. Growth Stages of Cabbage

Growth Stages	No. of Days
Seedling	25 – 30 Days After Sowing (DAS)
Recovery	5 – 7 DAT
Vegetative	25 – 30 DAT
Cupping	35 – 40 DAT
Head formation	40 – 50 DAT
Head filling	50 – 60 DAT
Mature/Harvesting	60 DAT

c. Land Preparation

Land preparation in cabbage production is crucial during wet season. Plow the area when the soil is just moist and friable. For upland and sloppy areas, set furrows at a row distance of 0.75 m. In lowland areas, raise the beds to .3m. The area should have good drainage.

d. Transplanting

For upland area, transplant 4 week-old seedlings on top of the furrows at a distance of 0.40 m between hills.

e. Irrigation

Irrigate the field at transplanting when the soil is dry. Succeeding irrigation depends on the occurrence of rain, and the condition of the soil at different stages of the crop.

Minimal irrigation should be done when the head has two distinct wrapper leaves to avoid cracking. Irrigate the field early in the morning or late in the afternoon to prevent the incidence of soft rot or head rot.

f. Fertilization

Cabbage responds very well to organic fertilizers. Compost or chicken manure is applied at planting at the rate of 10 tons per hectare.

Since cabbage absorbs its nutrients in large quantities during the head formation stage, it respond very well to split fertilizer application (10 days after planting), apply ¼ of N required; second application (30 days after planting), apply 1/8 of N required; and third application (at the beginning of head formation), apply ½ of N and half of K. Application of fertilizers should be done preferably after weeding. Split application is best suited in small farms where cheap labor is available and usual limiting factor is cash capital to buy fertilizers.

g. Pests and Diseases

Several insects such as Diamondback moth, cabbage worm, aphids, flea beetle, heart caterpillar are presently encountered by cabbage growers.

Major diseases of cabbage in seedbeds are damping-off and downy mildew. In the main field, a number of other diseases can occur and cause yield loss which occasionally can be severe. Such diseases are: black rot, soft rot, bottom rot, leaf spot, clubroot, black leg and some physiological disorders.

h. Weeding

Weed the area whenever necessary or according to the following schedule:

1^{st} weeding	-	14 DAT
2^{nd} weeding	-	28 DAT
3^{rd} weeding	-	42 – 56 DAT

i. Harvesting

First harvesting is done at 55 – 60 days after transplanting when the heads become firm and compact with two wrapper leaves intact. Always include 2-3 non-wrapper leaves intact at the head to minimize transport damage. Avoid coiling the heads as this favors rotting.

2. BOK CHOY /PAK CHOI (PECHAY)

a. Introduction

Pak-choi or Pechay (*Brassica chinensis* Linn) an annual or biennial herb is native to eastern Asia where it has been grown for thousand years. The crop originated from China and believed to be cultivated since 5th century. It is a leafy vegetable prepared either raw or cooked in several recipes. This leafy vegetable is smooth, about 30 cm high, broad at the tip and narrowing gradually toward the base which extends downward to the upper end of its elongated thick, whitish stalk.

Table 13. Varieties of Pak Choi

Variety	Maturity (DAS	Maturity (DAT)
Pavito	25 – 30	15 - 20
Black behi	25 – 30	15 - 20

b. Climate and Soil Requirements

Grows best in well-drained loam soils with a pH of 5.5 – 7.0. Clay soils and soils difficult to drain are not recommended for pak-choi production particularly during wet months. However, if grown in clay soils, use raised beds and plastic mulch to limit interception of rain and prevent accumulation of run-off water.

Pak-choi can be grown throughout the year but good yield can be attained when grown during cool dry season

c. Seeding

There are two methods of crop establishment. Pak-choi can be direct seeded or transplanted using raised bed or flat beds. Prepare seedbed at about 3cm high with a dimension of 1 m wide and 5 m long. The seeds can be broadcasted on top of the bed and then cover with soil. While line sowing can be done through making small furrows with a distance of 20cm between rows and the seeds are line sown.

d. Land Preparation

In loam soils, one plowing and one harrowing is enough to attain good soil tilth for pak-choi. However, in clay soils, two to three times harrowing is recommended to pulverize soil clods into smaller particles. Raised bed is more advantages over the flat beds during wet months growing season. It prevents flooding, which will lead to better plant stand thereby higher yield.

e. Preparation of Bed

There are two common types of beds used for pak-choi production. the raised bed and the flat bed. Raised beds are used during wet season planting to prevent flooding in case of heavy rains. The bed is raised about 30 cm in height with 1.0 m width. Weeding in this type of bed is much easier.

When direct seeded, the bed should be well pulverized in order not to hamper the germination of the very tiny seeds of the crop. If transplanted, the big clods should be reduced into smaller sizes.

f. Transplanting

Transplant pack-choi seedlings at 10 – 14 days after emergence. It is important to harden off the plants prior to planting to minimize transplant shock that can cause premature bolting (seed head formation).

g. Fertilization

The amount of NPK to be applied is determined through proper soil analysis, usually through the use of soil test kit. Among the major elements required by pak-choi, nitrogen is the highest enough to say that it is a voracious eater of nitrogen. The amount of application ranged from 70 – 120 kg per hectare depending on the inherent N fertility of the areas. Compost, P and K fertilizers are applied at the same time. N containing fertilizers, because of their solubility in water are applied in several doses. Below is the schedule of fertilizer application for direct seeded and transplanted pak-choi.

Table 14. Fertilization Schedule for Direct Seeded and Transplanted Pak-choi.

Methods of Planting	Schedule of Application	Amount (kg/ha)
Direct seeded	Pre-planting or last harrowing At 2 weeks after emergence At 3 weeks after emergence	All P and K and 1/3 of N All the require compost 1/3 of N 1/3 of N
Transplanted	Pre-planting or last harrowing At 2 weeks after transplanting	All P and K and 1/3 of N All the required compost 2/3 of N

h. Irrigation

Frequent irrigation is recommended to encourage brisk growth. Pak-choi should receive at least 1 inch of water weekly (irrigation or rainfall) for optimum yield and quality. Irrigation should be applied early in the day to allow plants time to dry before evening. This also facilitates lower field temperatures during the day, which is an additional benefit during warmer days of midsummer.

i. Insect Pest and Diseases

Insect which can cause damage to pak-choi include aphids, flea beetles and diamondback moth larvae. Flea beetles and DBM are the most common and can easily render a crop unfit for sale.

The common disease problems in pak-choi are damping-off (*Phytium sp*.), soft rot (*Erwinia caratovora*) and leaf spot (*Alternaria brassicae*). Diseases are most prevalent when there is excessive soil moisture.

j. Weeding

Use of handweeding is the most effective means of controlling weeds in pak-choi fields.

k. Harvesting

Pak-choi can be harvested at 25 – 30 days after sowing or 15 – 20 days after transplanting. It is not advisable to harvest in the hottest part of the day because the plant can wilt quickly. To harvest cut entire plant off at ground level, then remove any damaged leaves and trim root base. Pack loosely into boxes to allow adequate air circulation.

3. MUSTARD

a. Introduction

Yellow mustard is used mainly to produce "mild" prepared mustard for table use. It is also used in salad dressings, pickles and processed meat products. Brown and oriental mustard are used mainly for "hot" table mustard, and some for oil and spices.

b. Varieties

Yellow mustard varieties tend to be shorter, earlier maturing, and lower yielding than brown or oriental varieties.

c. Adaptation

Mustard is best adapted to fertile and well-drained soils. Avoid dry, sandy loam soils. Mustard has some tolerance to salinity and similar to barley in its productivity on saline soils. Yellow mustard varieties mature in 80 to 85 days; the brown and oriental types require about 90 to 95 days to reach maturity.

d. Seedbed Preparation

A seedbed for mustard should have no previous crop residue and be firm and fairly level. Shallow tillage, deep enough to kill weeds, will keep soil moisture close to the surface and leave the seedbed firm. This will permit shallow seeding and encourage rapid, uniform emergence. Seedbeds should be packed before planting with a roller packer, empty press drill or rodweeder.

Some producers are successfully planting mustard into standing small grain stubble and into minimum tilled stubble. The firm moist seedbed has been providing good stands.

mustard seeds

leaves

e. Growth Characteristics

Mustard seedlings emerge rapidly but tend to grow slowly after emergence. Under favorable moisture and temperature conditions, the ground will be covered in four or five weeks.

Five weeks after emergence, the plant will begin to bud. At this stage, the crop will appear rather uneven. A week to 10 days later the plant will develop into full yellow bloom and the stand will appear more even. Good moisture supplies favor a long blossoming period, and longer blooming periods result in higher yield potential. Full-grown plants vary in height from 30 to 45 inches, depending on type, variety and environmental conditions.

Table 15. Growth Stages of Mustard

Growth Stage	No. of Days
Seedling	10-15 Days after Sowing (DAS)
Recovery	3-4 Days after Transplanting (DAT)
Vegetative/Harvesting	15-20 DAT

f. Fertilizer

Mustard's response to nitrogen and phosphate fertilizer is similar to that of cereal grains. Avoid using more than 11.36 kg. of actual nitrogen per hectare, as seed germination injury can occur. Some growers mix low rates of phosphorus fertilizer with mustard seed and plant them together. Potash is rarely needed to increase mustard yields.

g. Weed Control

Weed control is important for successful mustard production. In the early stages of growth, young mustard seedlings do not compete well with weeds. However, once the plants are established they grow rapidly and shade out weed growth below the leaf canopy. Tame mustard is highly susceptible to many herbicides used to control broad-leaved weeds in cereal crops. Special precautions are necessary to avoid spray drift of these herbicides to mustard crops when spraying adjoining cereal crops.

h. Insects

Insects can cause serious yield losses, so growers should monitor fields closely for problems. Flea beetles and diamondback moth caterpillars have been the most troublesome insects.

Cultural methods can help to reduce plant losses from flea beetles. A firm seedbed that is well tilled and adequately fertilized will help plants to outgrow beetle damage during the susceptible early season stages.

i. Diseases

Several diseases attack mustard. Among the most serious is downy mildew, white rust, sclerotinia stalk rot (white mold). Leaf spot and virus mosaic. Do not include mustard in crop rotation systems containing crops such as sunflower, rapeseed, dry edible beans, crambe or safflower. These crops have similar disease problems and disease infestations can build to costly levels. Mustard grown in a small grain rotation is one of the best preventatives of serious disease problems and provides an excellent biological brake or cereal grain leaf diseases.

j. Harvesting

Wind, rain and normal drying generally do not cause mustard to shatter before cutting. But when the crop is overripe, actual harvesting operations can cause severe shattering losses. Yellow mustard can be straight combined if the crop has matured uniformly and is free of immature weeds. Full-seed maturity (no green seed) is necessary to produce a good quality sample. The reel may cause shattering during straight combining, but it can be removed or lifted above the crop if the stand is good. If the reel is needed, it should be reduced in speed and half the bats removed. Many growers of yellow mustard prefer to straight combine while the crops is still tough (12 to 13 percent moisture) and artificially dry. This gives seed of uniform quality.

Brown and oriental mustard varieties are generally more susceptible to shattering than the yellow types and are usually swathed. Brown and oriental mustard grow taller than yellow mustard, so the cutting height is higher. Swathing should begin when about 75 percent of the seeds have reached their mature color (yellow or brown). To minimize shattering losses, swathing should be conducted under conditions of higher humidity.

4. RADISH (Raphanus sativus)

a. Introduction

Radishes take many forms and are used in a large variety of ways world-wide. The common red and icicle types are commonly used fresh as salad vegetables and garnish in the U.S. Oriental types, such as the elongated and round daikon radishes, are less well-known in the U.S. but are important staple foods in countries like Korea, Japan, Taiwan, and others in Asia, and by these ethnic groups in the U.S. These types are used fresh, pickled (as is Kimchi), dried for future use, and cooked in countless Oriental dishes. Seeds of radish are sprouted and these sprouts are another important food in these Asian countries.

Many varieties of radish exist. Some are unique novelties, others are popular for home garden use, and still others are important in commerce.

b. Soil

Radishes do best on either light mineral soils or muck soils but may be grown on a wide range on soils. Daikon radish requires deep, friable soil for best quality roots.

Table 16. Growth Stages of Radish

Growth Stage	No. of Days
Seedling	10-15 Days after sowing (DAS)
Recovery	5-7 Days after Transplanting (DAT)
Rooting	25-30 DAT
Maturity	30-45 DAT

c. Seed and Treatment

Radish seed numbers approximately 70-140 per gram depending on type and variety. Use hot-water treated seed and fungicide treat seed to protect against several serious seed borne diseases. Hot water seed treatments are very specific (50^{O}C exactly, for 25 to 30 minutes; the wet seed then quickly cooled and dried). The seed treatments are best done by the seed company.

d. Seeding

Important: Before planting this crucifer crop, consider the following important factors:

1) No crucifer crop, or related weed has been present in the field for at least 2 years, 4 years preferable. Crucifer crops include cabbage, cauliflower, broccoli, kale,

kohlrabi, Brussels sprouts, Chinese cabbage, all mustards, turnips, rutabagas, radishes etc. Cruciferous weeds include wild radish, wild mustards etc. Also, crucifer plant waste should not have been dumped on these fields.

2) Soil pH should be 6.5 or higher. Soil pH over 6.8 is necessary to manage club root. The application of 1705.5 kg/ha. of hydrated lime, 6 weeks prior to planting is recommended for soils with pH less than 7.5 for club root control when planting club root susceptible radishes.

   Use a drill with a 5 or 10 cm. scatter shoe to drop 24 seeds 1.27 cm. deep per foot of row. Space rows 20 cm. apart. Growers commonly apply a mixture of sawdust and chicken manure to a depth of 1 to 2 cm. over the planted beds.

   In-row spacing should be 10-15 cm., with rows 60-90 cm. apart. Adjust planting rates accordingly. Some Chinese radishes can weigh 45 kg. These would be spaced 60-90 cm. apart in rows 36-48 inches apart.

e. Fertilizer

A soil test is the most accurate guide to fertilizer requirements. The following recommendations are general guidelines.

Maintain a pH 6.5-7.0, adding lime or dolomitic lime (if magnesium is needed) as indicated by soil test.

For red globe radish, poultry manure is often used to supply 57-85 kg N/ha. Care is needed to guard against excessive N is particularly bad during periods of warm, wet weather. Buildup of soil N during the season results in progressively larger tops, so N applications should be reduced as the season progresses.

Nitrogen rates for radish should be 148-170kg/ha. Divide this among several applications, applying two thirds of the total during the last half of the growth period. Adjust N rates and irrigation as necessary to maintain vigorous, uniform growth.

In the absence of a soil test, for both red globe and daikon radish, P, K, S and B, should be applied as follows:

Phosphate: 148-170 (P_20_5) kg/ha.
Potash: 114-170 (K_20) kg/ha.
Sulfur: 34-57 kg/ha. per season
Boron: 1-6 kg/ha., or as needed according to soil test.

If fertilizer is to be banded at time of seeding, rates greater than 68kg/ha of potash should be broadcasted and incorporated before seeding.

f. Irrigation

Globe radishes are shallow rooted and quick growing, requiring frequent, uniform irrigation for optimum growth and tenderness. Earliest plantings may receive sufficient rain to mature the crop, later plantings may need a total of 12-15 cm. of water depending on planting date, seasonal variation, and variety. Use care to prevent excessive top growth.

Soil type does not affect the amount of total water needed, but does dictate frequency of water application. Lighter soils need more frequent water applications, but less water applied per application.

C. CUCURBITACEAE FAMILY

1. CUCUMBER

a. Introduction

The cucumber (*Cucumis sativus*) is a member of the gourd family (Cucurbitaceae) as are melons, squash and pumpkins. Cucumber is a well known fruit with its many uses in a variety of food preparation. Pickled cucumber is a universal ingredient in salads, dishes, dips, sauces and gravies. Fresh cucumber is also widely used in the preparation of sandwiches and burgers and may be eaten raw or cooked. When eaten regularly, it helps cure kidney ailments. The fruit extracts are used in the preparation of cosmetics and medicine as well.

b. Climate and Soil Requirement

A sandy loam to clay loam soil, high in organic matter, is ideal for growing cucumber. Soils that cake or crust result in poorer stands. The soil should have good drainage and should be naturally fertile. An ideal soil pH is 6.0 to 6.5.

Cucumber is a warm season crop grown year-round locally. The optimum temperature for growth is about 30°C, while the optimum night temperature for growth is 18-21°C.

Table 17. Varieties of Cucumber

Variety	Maturity (DAS)
Green beret F1	48 – 50
Jackson 27 F1	45 – 48
Poinsett	50 – 52
Ambasador F1	45 – 48
Governor F1	50 – 52
Champ 11	37 – 40
Explorer	60
Panorama	60
Bituin	60
Palmaria	60
WPL Cu1	60
WPL Cu2	60

Table 18. Growth Stages of Cucumber

Growth stage	No. of Days
Seedling	7 – 10 days after sowing (DAS)
Vegetative	15 - 20 DAS
Flowering	20 - 30 DAS
Fruiting/Harvesting	30 – 55 DAS
Maturity	60 – 70 DAS

c. Land Preparation

Well prepared soil is important in obtaining uniform emergence of cucumber plants. Prepare the field at least one month before planting. Follow each plowing with harrowing and allow weed seeds to germinate between each plowing. Prepare furrows 75 cm to 100 cm apart. For wet season cropping, prepare raised beds instead of furrows. One week before planting, make holes 30 cm apart and apply well decomposed animal manure at the rate of 200 g/hill. Mix the manure thoroughly with soil.

d. Planting

About 2-3 kg of seeds are required for one hectare. Sow 2-3 seeds/hill and cover with a thin layer of soil. Irrigate the field right after sowing. Five to seven days after germination, rogue excess seedlings and maintain only two plants per hill.

e. Trellises

Construct trellises using bamboo or wooden posts spaced 3-4 m apart. GI wire #16 can be used to connect the poles along each furrow. Abaca twine or synthetic straw can be used for vine training.

f. Training

Train the vines daily as soon as the tendrils appear, to prevent the formation of deformed fruits. Properly trained vines provide shades to the inner part of the lot and prevent the growth of weeds.

g. Fertilizer

Apply fertilizer based on soil test recommendation. Lime, as required, should be plowed in as early as possible. Apply complete fertilizer at the rate of 10-15 g/hill together with compost during planting. Sidedress remaining nitrogen, phosphorous and potassium (NPK) three weeks after transplanting.

h. Irrigation

Irrigate in between plots at planting. For sandy loam, irrigate the field twice a week, and for clay loam soil, once a week. Final irrigation must be done before the last week of picking (50-55 days after emergence).

i. Pest and Diseases

Pests attacking cucumber are beetles, leaf folders, aphids, thrips, and mites. If pest population is high, it will significantly affect the yield of cucumber. Powdery mildew and downy mildew are the common diseases that affect cucumber.

j. Pest Control

Crop rotation and the use of resistant varieties and disease-free seeds are the most economical methods of pest control. Mulching with straw or plastic will greatly help in controlling weeds and is very beneficial from the standpoint of moisture conservation and stability. Plastic also produces an earlier crop.

k. Weeding

Weeds cause considerable yield loss if not controlled early in the season. Control includes light cultivation, spot hand-weeding, tillage and mulching.

l. Harvesting

First harvesting is expected in 35 days after emergence.

2. SQUASH (*Cucurbita pepo)*

a. Introduction

Summer squash is defined as fruit of the Cucubitaceae family that are consumed when immature, 100% of the fruit of which is edible either cooked or raw. However, once picked it is not suited for long-term storage. Squash has a soft rind which is easily penetrated, and the seeds of which would not germinate at harvest maturity: e.g. *Cucurbita pepo* (i.e. crookneck squash, straightneck squash, scallop squash, zucchini, vegetable marrow).

b. Soil Type and Temperature

Squash grows best on fertile, well-drained soil supplied with organic matter. The ideal pH for squash growth is between 6.0 to 7.5, but it will grow on soils with a pH of up to 8.0. Consult a soil test for fertilizer and liming recommendations.

The minimum soil temperature required for germination of squash 15^{O}C, with the optimum range between 21 ^{O}C and35^{O}C.

c. Seeding

Use 91-101 cm. spacing between rows with plants 18-36 inch apart within the row.

Table 19. Growth Stages of Squash

Growth Stage	No. of Days
Seedling	7-15 Days after Sowing (DAS)
Vegetative	20-35 DAS
Flowering	40-55 DAS
Fruiting	60-75 DAS
Maturity	80-95 DAS

d. Fertilizer

- A soil test is the most accurate guide to fertilizer requirements. The following recommendations are general guidelines:
- The optimum pH range is 5.8-7.0. Apply 2.5 tons/ha of manure in the spring when available.
- Nitrogen: 57-80 (N) kg/ha (Sidedress with an additional 30-60 lb N per acre when plants begin to flower).
- Phosphate: 130-142 (P205) kg/ha.
- Potash: 57-114 kg K20/ha. (broadcast and disked-in prior to seeding).
- Sidedress with 28-57 kg N/ha, or where mulching and trickle irrigation are practiced, N can be fed through the trickle irrigation system at 17-28 kg/ha when the vines begin to spread. To prevent clogging or plugging from occurring use soluble forms of nitrogen (urea or ammonium nitrate) and chlorinate the system once a month with a 10-50 ppm chlorine solution. Chlorinate more frequently if the flow rate decreases.

e. Irrigation

Summer squash roots to a depth of 90-120 cm. Maintain soil moisture above 60% of the soil water holding capacity. It is important to regulate irrigation properly to avoid excessive moisture or water stress. Research has shown that the use of drip irrigation under black plastic mulch is superior to sprinkler irrigation with black plastic mulch. Yields usually increase dramatically.

f. Flowering and Pollination

Summer squash plants bear separate male and female flowers on the same plant (monoecious). Only the female flowers set fruit. Bees transfer pollen from male flowers to female flowers, making fruit set possible.

It is recommended that one honey bee hive should be introduced for every 0.40-0.80 ha during the blooming period since native bee populations may not be adequate, or may not coincide properly with the blooming period.

Questions arise in relation to cucumbers, melons, gourds, and summer and winter squash, crossing and affecting the eating quality of one vine crop or another. This is not a problem. Intercrossing is only a problem when seed is saved for replanting, in which case squashes of the same species need to be isolated for crop purity. Cucurbits of different species do not intercross sufficiently to create problems for seed producers.

3. <u>BITTER GOURD</u> (*Momordia charantia*)

a. Introduction

Bitter gourd (*Momordica charantia*) is a member of cucurbit family and one of the most popular vegetables in Southeast Asia. Native to China or India, the fast growing vine is becoming popular worldwide. Depending on location, bitter gourd is also known as bitter melon, karella, balsam pear or ampalaya. It is usually grown anytime of the year for its edible young shoots and fruits which promise a good supply of nutrients such as vitamins and minerals.

The young fruits and tender vine tips are used in a variety of culinary preparations. The medicinal value of the gourd in the treatment of infectious diseases and diabetes is attracting the attention of scientists worldwide.

b. Climate and Soil Requirement

Bitter gourd thrives in the tropics from lowland areas to altitudes of up to 1,000 m. It requires a minimum temperature of 18^{0}C during early growth, but optimal temperatures range from 24-27^{0}C. It thrives more in lower temperatures compared to other gourds, but cool temperatures will retard growth and frost will kill the plant. The plant is adapted to a wide variety of rainfall condition, but regular irrigation is needed to ensure high yield.

Bitter gourd tolerates a wide range of soils but prefers a well-drained sandy loam soil that is rich in organic matter. The optimum soil pH for bitter gourd is 6.0 – 6.7, but plants tolerate alkaline soils up to pH 8.0.

Table 20. Varieties of Ampalaya

Variety	Maturity (DAS)
Galaxy F1	48 – 52
Jade star L F1	48 – 52
Jade star XL F1	53 – 57
Sta Rita	55 – 60
Sta Isabelle	55 – 60
Native	55 - 60

Varieties of bitter gourd differ in fruit size, color, ridging, and degree of bitterness

Table 21. Growth Stages of Ampalaya

Growth stage	No. of Days
Seedling	7 – 10 days after sowing (DAS)
Vegetative	30 – 35 DAS
Flowering	40 – 45 DAS
Fruiting/Harvesting	48 – 55 DAS
Maturity	60 – 70 DAS

c. Land Preparation

The field should be well-prepared and the soil must be well pulverized and leveled. If the soil pH is lower than 5.8 apply lime one month before planting at the rate of 1,000- 3,000 kgs/hectare depending on the soil acidity.

d. Planting

There are two options in planting bitter gourd, direct seeding and transplanting.

Direct Seeding

Sow the seeds 2 cm deep at a spacing of 30 cm between plants and 300 cm between rows. Other recommended spacing are: 200 cm x 50 cm; and 100cms x 100 cm. The recommended spacing will give you 10,000 plants/hectare or one plant/sqm.

Transplanting

Sow the seeds 2 cm deep in any kind of small plastic bag or small container using a potting mix that has good water holding capacity and good drainage. Water the seedling thoroughly every morning to maintain a moist but not wet soil. Grow the seedlings in full sun with adequate protection against heavy rains, winds and stray animals. Harden the seedlings by reducing the watering three days before transplanting. At transplanting, remove the plastic bag or container with minimum disturbance to the roots. Do not delay transplanting too long beyond the first true leaf stage. Transplant on cloudy days or late in the afternoon. Transplant seedlings into the field at spacing similar to those used for the direct seeding method.

e. Fertilization

Bitter gourd responds well to the use of organic fertilizer. If ever possible organic fertilizer should be given at sowing time. If high amounts of organic fertilizers are used (more than 5,000 kilos of pure manure per hectare) the rate of usage of inorganic fertilizers may be reduced. Fertilizer application rates depend on the soil type, fertility level, and soil organic matter. In sandy soils, fertilizer application consists of a basal application followed by four sidedressing. In clay or heavy textured soils, the entire amount of P, and one-third of N and K is applied before planting, either by broadcasting and tilling or by banding a few centimeters deep and to the side of the plant row in the bed. The balance of N and K is applied in two or more sidedressings. No matter the soil type, the first sidedressing is applied when plants have four to six true leaves.

f. Staking and Trellising

Bitter gourd grows very fast and vines elongate rapidly within two weeks after planting. Thereafter, the plant sends out lateral stems. Staking and trellising will increase fruit yield and size, reduce fruit rot, and make harvesting easier.

There are several methods of trellising bitter gourd. Bamboo poles, wood stakes, PVC pipes or other sturdy materials are used to provide support and keep the fruit and foliage off the ground. The trellis is arranged either in a lean-to or tunnel structure. The trellis should be 1.8-2.0 m high, constructed from stakes 1.2-1.8 m apart, which is almost similar to the plant row spacing.

Lean-to trellis structures

For the lean-to type, the stakes are joined between two adjoining beds forming an A-shape structure. Horizontal stakes are installed at the top joining all other beds. The stakes support the climbing vines and lateral stems. Strings are used to secure adjoining stakes. Planting is easier to manage and more productive when 2-m high string trellises are used rather than 1-m- high trellises.

For tunnel type, plants are grown inside an arch-shape structure made of either PVC or galvanized iron pipe. Plants are supported by bamboo stakes where vines freely climb and reach the top. The vines and lateral stems grow along the structure.

Another type of trellising consists of a system of string that runs between the top and bottom of horizontal wires, or horizontal wires that run across all directions as top.

Tunnel trellis structure

Horizontal trellis on top of structure

g. Pruning

To improve yield, remove lateral branches until the runner reaches the top of the trellis. Leave 4-6 laterals and cut the tip of the main runner to induce early cropping. Removal of lateral branches in the first 10 nodes has a positive effect on the total yield.

h. Irrigation

Avoid water logging and/or lack of water. Bitter gourd does not like water logging nor lack of water. Irrigate the field two weeks after emergence by flooding method. Repeat irrigation every seven days throughout the growing season of October to December and as the need arises in the May to July planting. Delayed irrigation during the dry season will reduce the fruit yield and quality. Weekly irrigation during the dry season is a normal frequency.

i. Pests and Diseases

Fruit fly is the most destructive insect pest of bitter gourd. This fly is difficult to control because its maggot feeds inside the fruits, protected from direct contact with insecticides. Beetles, thrips, cutworms, ballworm aphids and mites are the other pests that affect bitter gourd.

Bitter gourd is susceptible to any diseases. It is a host of watermelon mosaic potyvirus and it can be infected by downy mildew, cercospora leaf spot, bacterial wilt, fusarium wilt, and root knot nematode. Fungal infection often occurs during prolonged wet periods.

j. Weeding

To suppress the growth of weeds, mulching is done. Mulching is also done to conserve water. Hand and hoe weeding can be performed as needed

k. Harvesting

Bitter gourd requires close attention during harvest time. The fruits develop rapidly and must be harvested frequently to keep them from becoming too large or too bitter. Fruits should be light green, thick and juicy, and the seeds should be soft and white. Bitter gourd can be harvested every 2-3 days using a pair of scissors or a sharp knife to cut the fruit stalk. If a fruit remains too long on the vine, it will turn spongy, sour, yellow or orange, and it will split open.

4. CHAYOTE

a. Introduction

The chayote plant has climbing vines and leaves resembling those of a cucumber's. In the tropics the plant is a perennial with stems full of tendrils. The stem grow for 15 or more meters long. It produces separate male and female flowers, and bees are required for pollination. The light green, pear-shaped fruit contains a single, edible seed about one to two inches long. Varieties range from almost smooth to deeply ridged and from cream to apple green in color. It may have nonsticking prickles covering it. The fruit may weigh from 0.23 to 0.28 kg and is 7 to 20 cm long. It was cultivated centuries ago in Central America by the Aztecs and Mayans.

b. Culture

Climatic requirements

Chayote is a warm season crop. Vine growth is luxuriant in less favorable climatic conditions, but fruit production may be greatly reduced. Chayote blooms when daylight is shortened in late summer through fall. The fruit must mature before the cooler days.

Propagation and care

Some types of trellis or support are required to produce chayote. Structures similar to grape arbors are frequently used. With vine growth trained over the top, fruits can be harvested from below. Vertical trellises are also used. Plant one fruit per hill, in hills spaced 3.65m apart and in rows spaced 3.65m apart. Stem cuttings may provide greater uniformity of plant type. It can be planted with the whole fruit on its side and the stem end sloping upward. Fruit obtained from a supermarket will sprout when kept in subdued light, and are ideal for planting. Fertilization is similar to summer squash. In many areas both nitrogen and phosphorus fertilizer are required. Irrigation may be required one to two times per week depending on temperature and soil texture.

Extremely mature fruit will sprout on the vine and are still edible depending on the cuisine prepared.

c. Pests

Leaf-eating beetles and snails occasionally reduce plant growth. Leaf-feeding insects, unless seriously damaging plant growth, seldom require control measures. Nematodes occasionally reduce chayote yields and have to be controlled several weeks prior to planting.

d. Post harvest Handling

Chayote fruits are often individually wrapped in tissue paper or polybags (to reduce friction and water loss) in single-layer flats. Increased decay is sometimes observed on fruits stored in polybags since moisture condensation on the fruit surface is increased. Germination of the seed is a problem if the fruit is held at temperatures above 13-14^{O}C (56-58^{O}F). The chayote is also susceptible to chilling injury. It shows distinct chilling symptoms depending on the storage temperature. For example, surface bronzing occurs on fruits held at 2.5-5^{O}C (36-41^{O}F), and surface pitting, decay and internal browning appear in storage at 5-7.5^{O}C (41-45^{O}F). A storage temperature of 7.5-10^{O}C (45-50^{O}F) should extend shelf life up to 4 weeks.

5. LUFFA SPONGE GOURD

a. Introduction

Luffa sponge gourd (*Luffa aegyptiaca* Mill) is an annual tropical or subtropical vine known for its fruit. The fruit can be eaten at the green or immature stage, but it is more commonly used at the mature stage for the sponge. The skin of the fruit, or gourd, is initially green and turns brown at maturity. As the gourd matures, a dense fibrous network of cellulose forms inside the fruit, and this is what is harvested and used as a sponge. The fibrous network provides support for the fruit and serves as a mechanism for seed dispersal. The sponge has a variety of commercial purposes including personal hygiene products, household cleaning products, steam engine filters, craft items, insulation, padding for saddles, and immobilizing agents in biotechnology.

b. Selecting Seeds and Producing Transplants

Presently, one of the most difficult aspects of entering into commercial luffa sponge gourd production is obtaining large volumes of high quality seed. Many of the luffa seeds sold for home gardens produce small, low-quality sponges with weak fibers. Once the desired quality of the luffa sponges has been produced, the seeds must be saved. It must also be remembered that luffa gourds cross- pollinate easily. Thus, to maintain the same high quality luffa that is close to the original, different luffa cultigens must **not** be grown within 450m of each other.

Luffa seed germination is often slow and sporadic. To obtain good plant quality standards, luffa gourds should be produced from transplants. 1) Soak seed in warm water for 24 hours prior to seeding. 2) Sow seeds, two to three per cell, in flats. 3) Thin to one plant per cell after the first true leaves appear. 4) Grow for 4-6 weeks in a greenhouse at about 149-158˚C. 5) Luffa should be transplanted outdoors after all danger of frost is past.

c. Site Selection and Fertilization

Luffa gourds require a well-drained soil in a location where they will have full sun and good air circulation. Conduct a soil test prior to planting and follow lime and fertilizer recommendations for cucumbers. Two or three times during the growing season add 9-11kg nitrogen per acre as a side-dress or through the drip-irrigation system.

d. Planting and Trellising

To speed growth in the spring in cooler climates, luffa gourds should be grown on raised beds with black polyethylene mulch irrigation. This is required with drip-irrigation being the preferred method. Luffa sponge gourds benefit greatly from being grown on a trellis system. If luffa gourds touch the ground, rotten fruit, discolored sponges and misshaped gourds are usually the result. A vertical trellis, similar in design to the ones used for trellised cucumbers and pole beans, is most commonly used. It must, however, be **very sturdy**. To support the weight of mature gourds, 4”×4” posts set 3 meters apart are recommended. The top horizontal support should be a heavy gauge wire or cable. Several other wires can be run between the top and bottom wires in a V-pattern, as for the pole beans. Nylon mesh can also be used.

Space rows can be 1.5 or more meters apart to accommodate equipment. In-row spacing of 3.6-5.5 meters has produced the highest yields of marketable sponges. The plants need to be hand trained weekly until they reach the top wire. Try to keep all fruit off the ground and away from the trellis wires. Prune plants by removing the first four lateral shoots (from the soil line upwards). As for all cucurbits, luffa gourds need to be pollinated. Position one or two hives of bees per acre nearby when the plants are in full bloom to ensure adequate pollination.

Table 22. Growth Stages of Sponge Gourd

Growth Stage	No. of Days
Seedling	7-15 Days after Sowing (DAS)
Vegetative	20-45 DAS
Flowering	45-75 DAS
Fruiting	75-105DAS
Maturity	105-120 DAS

e. Pest Control

Cucumber beetles, spider mites, mildews, and viruses have been minor problems. Practice crop rotation, prune as described above, and use drip-irrigation to reduce chances of having disease problems.

f. Harvesting

Harvest immature fruit every 3-4 days at a size of 10-15 x 2-5 cm, 12-15 days after fruit set, which occurs 9-13 weeks after planting. Fruit must be eaten at this stage since the fruit develops purgative chemicals and becomes fibrous as it matures. Sponges are harvested from the smooth luffa at maturity, about 4-5 months after planting.

Seeds can be removed before or after the skins are removed. If the skins are intact, break the cap off the distal (bloom) end of the dried gourd and shake the gourd or beat two gourds together. Depending on the final intended use for the sponge, seed removal can be done faster by cutting the sponge perpendicular to the long axis (as for bath sponges) or along the long axis (to make mitts and pads). Save seeds from good sponges for the next growing season.

D. LEGUMINOSAE FAMILY

1. POLE BEANS

a. Introduction

String beans locally known as pole sitao is an annual plant commonly grown in the Philippines. Botanically, it is known as *Vigna unguiculata* subsp. *sesquipedalis* (Fruw). It provides a good supply of nutrients like proteins, minerals and vitamins. In the Philippines, it is usually grown for its fresh pods or dry seeds.

b. Climate and Soil Requirement

Any type of soil is suited for string beans production. However a friable, fertile, well-drained soil relatively free from diseases is preferable to obtain the best yield. The soil must have a pH value of 5.5 – 6.8. If soil test indicates that lime is needed, apply dolomitic lime in the amount recommended. The soil should be well supplied with organic matter.

Table 23. Varieties of Pole Beans

Variety	**Maturity (DAS)**
Sandigan	55
Tender long	55
6001 XL	60
Sierra madre	50
BPI PS3 (Maagap)	45
EGPS 1	55 – 60
CSL # 19	55 – 60
Green Maxi	55 – 60
6009	55 – 60
DES Pole sitao	55 - 60

Table 24. Growth Stages of Pole Beans

Growth Stage	No. of Days
Seedling	10 – 15 Days After Sowing (DAS)
Vegetative	15 – 35 DAS
Flowering	35 – 45 DAS
Fruiting/Harvesting	45 – 80 DAS

c. Planting

Pole sitao can be planted anytime of the year. But for best quality green pods and profit, May to June or October to November is preferable under Type 1 climate. For dry beans production, planting is best from January to March.

1) Drill the seeds directly in the furrows at a distance of 1 m between rows and 50 cm between hills. 2) Drill 2 – 3 seeds per hill at a depth of 2.5 – 3 cm. 3) Twenty kilograms of seeds are needed for a hectare of string beans production.

d. Fertilization

It is always best to test the soil and follow the recommendation based on the analysis. In the absence of soil analysis, this recommendation can be used in one hectare of string beans. Apply 5 tons of chicken manure or 33 bags organic fertilizer before first plowing. Two weeks after planting, apply 4 bags of 14-14-14 in a spot method. Spray the crop weekly with foliar fertilizer after the first harvest.

e. Irrigation

Irrigate the field every week throughout the growing period of string beans production.

f. Supporting and Training

To produce more and good quality pods, provide mechanical support or trellis for the climbing vines. Place wood or bamboo poles or stake with a height of 2m spaced at 50 cm apart along furrows before seeding. The vertical single support is the most economical.

g. Pest and Diseases

Bean plants can be attacked by various biting, chewing and sucking insects. Among the most troublesome are leafhoppers, green stink bugs and been beetles.

Beans planted in the summer and fall are exposed to soil fungi that can kill the plants soon after they come up. Soil fungi such as *Phytium* and *Rhizotonia* can invade the plant and kill it by the time the plant reaches the four-leaf stage.

h. Weeding

When weeds start to appear, light weeding with the use of a hoe should be done to eliminate the germinating weed seeds. The plots must be weeded free throughout the critical period of competition (CPC), after which the plant can be allowed to grow until harvest.

i. Harvesting

Harvest string beans from 45-55 days after emergence. The pods are harvested either as green or dry pods depending on the purpose. Usually, green pods are ready for harvest 7-10 days after flowering. To prolong the production period of the plant, pick the pods every two days.

On the other hand, harvest dry pods when majority have turned yellow and have started to dry up. Dry the pods under the sun or by means of mechanical drier.

E. SOLANACEAE FAMILY

1. TOMATO

a. Introduction

Tomato (*Lycopersicon esculentum Mill.*) is a member of the family *solanaceae*. The tomato is often considered as vegetable but actually it is a fruit that has become a major world food crop. Tomato has become very popular among consumers because it is a good source of vitamins A and C in diets. Various pest and disease species that attack tomato can cause economic loss.

b. Climate and Soil Requirements

Tomato is a day neutral plant. Its fruits contain higher ascorbic acid with high light intensity. It needs different temperatures for each growth development stage:

Seed germination	26 - 32°C
Seedling growth	25 – 26°C
Pollen germination & pollen tube growth	22 – 27°C
Fruit setting	18 – 20°C
Fruit ripening	24 - 28 °C

High day temperatures (>40°C) can abort the flowers due to physical destruction of pollen grains.

Tomato thrives on many soil types. It grows best in fairly fertile, well-drained sandy loam soil or heavier soils and soil free from root-knot nematodes and bacterial wilt organisms. The soil organic matter must be at least 1.5%, with a pH of 4.3 – 8.7 (growth is optimum at pH 5.5 – 6.5). Tomato is moderately tolerant to acidity.

Table 25. Varieties of Tomato

Variety	Maturity (DAT)
Diamante	55
Marimar	60 – 65
Maxima	55 – 60
Improve pope	60 – 65
Cardinal	70
Apollo	60
Tabeth F1	65
Mapula	60

Marilag	60
Marikit	60
BPI Claveria	60
VC48 – 1	60
CA 633	60
CA 530	60

Table 26. Growth Stages of Tomato

Growth Stage	No. of Days
Seedling	25 – 30 Days after Sowing (DAS)
Recovery	5 – 7 Days After Transplanting (DAT)
Vegetative	25 – 30 DAT
Flowering	30 – 45 DAT
Fruiting	45 DAT
Maturity	55+ DAT

c. Seedling Production

Select a variety that is tolerant of moisture or rain as well as heat. Select also those that are resistant to bacterial wilt, and fruit cracking. Sow seeds thinly on shallow furrows spaced 5 cm apart. Cover them and press the soil gently to prevent seed exposure when watering. Water every morning. One week after emergence or when the first true leaves start to develop, prick off the seedlings. This is done by transferring the seedlings to another seedbox or seedbed at a spacing of 5 cm x 5 cm. This will enhance better growth and development.

Harden the seedlings at least 1 week before transplanting by gradually exposing them to direct sunlight and withholding water. Hardened seedlings are stronger, shorter-stemmed, and with thick dark-green leaves. Block seedlings by passing a knife between the seedlings to facilitate removal of the seedlings from the seedbox with minimal damage to the root system.

Water the seedbed or seedbox a few hours before transplanting so that the soil will adhere to the roots of the seedlings.

d. Land Preparation

Prepare land by plowing and harrowing twice. Make furrows or shape the land into beds and grow tomatoes on top.

Mulching with rice straws, thin polyethylene plastic sheets, or other material is used to cover the soil surface. Mulches reduce fertilizer leaching, conserve moisture, and reduce weeds. Tomato tends to produce more fruits and lower prevalence of growth cracks when mulched.

Spindly and healthy seedlings

e. Transplanting

During dry days, transplant late in the afternoon to minimize wilting and to hasten the recovery of the newly transplanted seedlings. Insert the seedling in a hole so the cotyledons are above the surface. Tall, thin (spindly) seedling should be buried deeper. Press soil firmly around the root, and water around the base of the plant to settle the soil. Irrigate the field as soon as possible after transplanting. Transplant tomato seedlings 3-4 weeks after sowing with a distance of 75-100 cm between rows and 30-50 cm between hills.

f. Fertilization

Among the three major nutrients (NPK), lesser potassium (K) is required than nitrogen (N) and phosphorous (P) in vegetable. However, K is usually applied to tomatoes because of their high requirement. Long-term studies on the response of tomatoes to K show a positive effect on yield.

In the tropics, the amount of fertilizer used depends on local soil conditions and cropping patterns. The most common fertilizer application rates are: 60-120kg N/ha; 60-140 kg P_2O_5/ha; and 60-120 kg K_2O/ha. In soils with high cation exchange capacity and in young soils 60-90-150 kg N,P_2O_5 and K_2O/ha for determinate and indeterminate varieties are recommended.

The common fertilizer sources used to supply the above requirements are: Urea or Ammonium sulfate, triple superphosphate, and muriate of potash.

Appropriate soil analysis will indicate the level of NPK in the soil and thus, the range of NPK application required.

g. Irrigation

Tomato is most sensitive to water deficit during flowering, somewhat sensitive immediately after transplanting and during fruit development and least sensitive during vegetative growth.

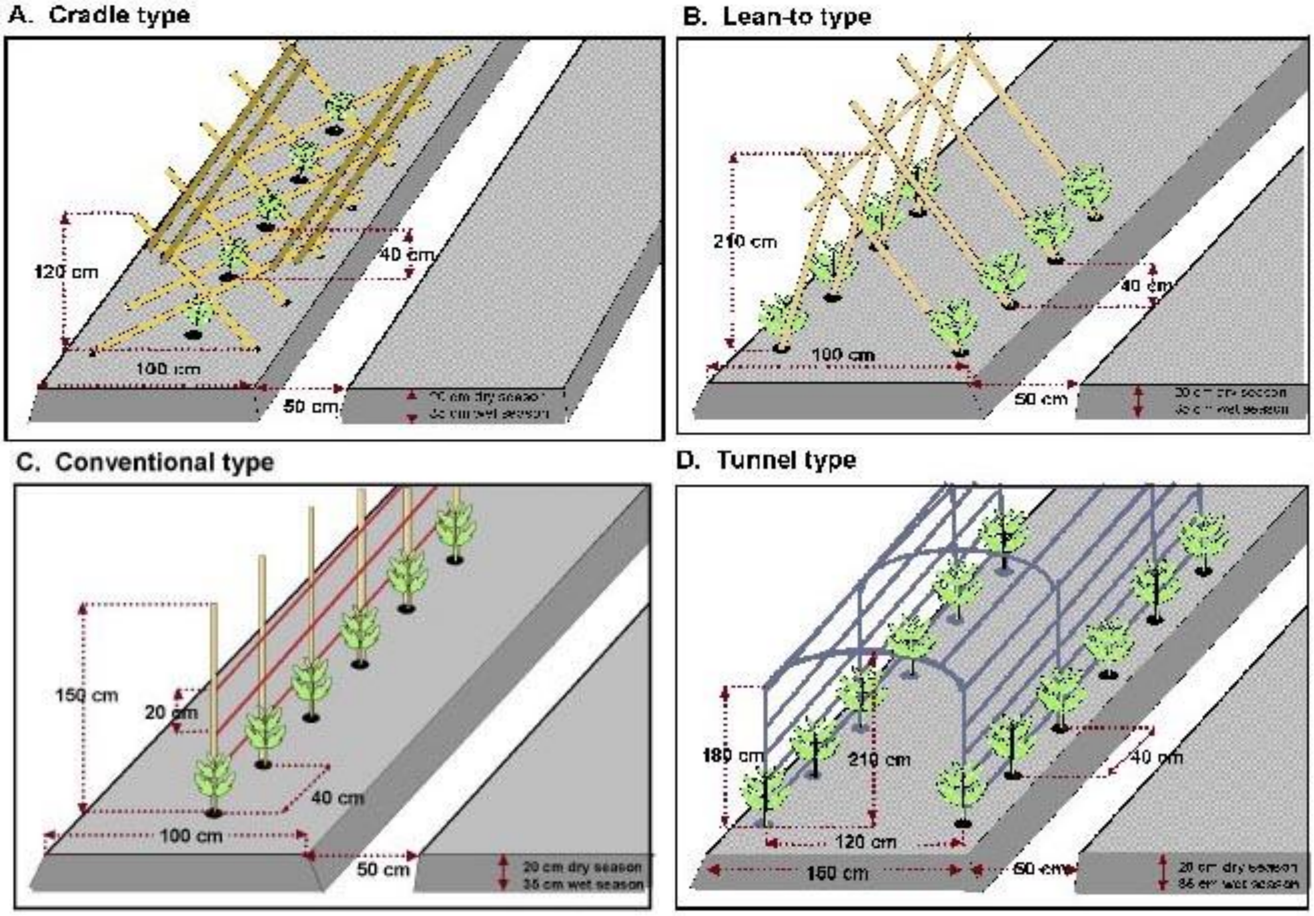
Tomato requires 460 mm water per crop. It is sensitive to water logging which it can tolerate for only less than 7-8 hours. Consequently, many tomato cultivars succumb to infection in wet soils because of susceptibility to pathogen brought about by the change in pathogen population and the probability of root contact with bacterial cells.

During dry season, tomato yields satisfactorily in clay soils with three to four irrigations. Six irrigations are needed in light loam soil. Drought in tomatoes will result in small fruits and spindle stems or branches. In most cases, it also results in the rotting of the blossom ends because of low calcium absorption.

h. Staking

Tomato plants should be staked 3-4 weeks after transplanting. Indeterminate varieties should be staked to facilitate pruning, pinching, harvesting, and other cultural practices. On the other hand, determinate varieties should be staked in the wet season to prevent fruit contact with the soil. Stake or trellis tomato plants with bamboo poles, wood stakes or any other materials that could provide support and keep the fruits and foliage off the ground. Staking can increase fruit yield and size, reduce fruit rot, and make spraying and harvesting easier. Plants should be fixed securely to the stake or trellis by string supports.

Staking arrangements



i. Pruning

Pruning (selective removal of side shoots) results to earlier maturity, bigger size, uniformed fruits and ensures proper fruit color as it allows the sun to reach the fruits. Care should be taken to leave enough of foliage to shade the fruit and protect it against sunscald.

Pruning should be done regularly, starting at an early stage because when done later in the season, it becomes difficult to distinguish between the main stem and the suckers.

j. Pest and Diseases

Tomato fruitworm (*Helicoverpa armigera*) is a highly voracious insect and is considered one of the major pests of the world's food and fiber plants. High population of cutworm and armyworm can contribute to the loss in production, as well as the attack of whitefly that carries viral diseases. The damage on the leaf of leafminer also affects the ability of the plant to manufacture food, thus reducing the capacity to develop fruits.

Tomatoes are susceptible to diseases. Damping-off bacterial wilt, bacterial spot, fusarium wilt, late blight, nematodes and a number of viral diseases are some of the diseases that could infect tomatoes.

k. Weeding

Weeds should be controlled in tomato crops because they compete for light, water, and nutrients. Sometimes they host tomato diseases like the tomato yellow leaf curl virus. Mulches suppress weed growth on the beds. Remove weeds from furrows by pulling or hoeing. Off-barring and hilling-up are also recommended for effective weed management.

l. Harvesting

Harvesting depends on the purpose for which the tomatoes are grown and the time of shipping/distance to market.

Tomato is harvested when the fruit starts to show cream streaks at the blossom end (mature green); when the blossom end turns pink or reddish (breaker); and when full red skin is attained (red ripe).

Place the harvested fruits in bamboo (kaing) or wooden crates lined with banana leaves or bracts for protection from mechanical damage. To prolong the storage life, tomato should be stored at 7.2-10 °C and 85- 90% relative humidity.

2. EGGPLANT

a. Introduction

Eggplant (*Solanum melongena* L.) is known as aubergine (Europe), brinjal (India and Bangladesh), talong (Tagalog), tarong (Ilocano), or bringhinas (Bisaya). It is cultivated for the immature fruits which are either roasted, fried, boiled, baked, pickled, or processed and can be used in stews or for garnishing.

Preferred eggplant types are the long, purple varieties with green calyx, but some regions also prefer the long or round, green-colored varieties. Eggplant is generally cultivated as mono-crop year-round type of plant.

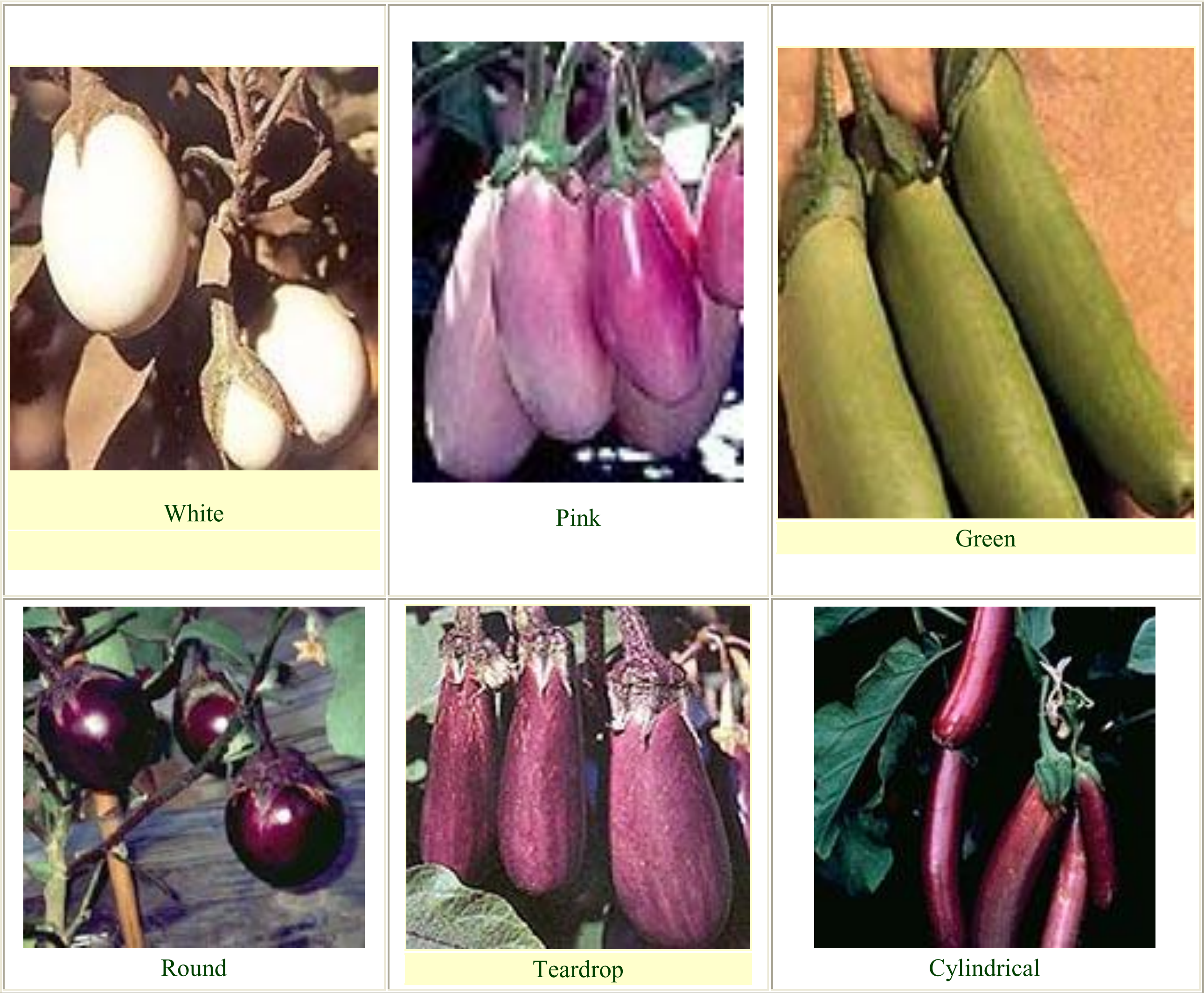
b. Climate and Soil Requirements

Eggplant is a warm season vegetable adapted for year round production in the tropics. It is not sensitive to daylength and can grow and flower freely anytime of the year. Its temperature requirement is 25-35°C (day) and 20-27°C (night). It is tolerant to hot night temperature.

Eggplant is moderately tolerant to salinity and can grow at pH 4.3 – 8.7 (optimum pH 5.5 – 6.8). It is best adapted to fairly fertile, well-drained loams but can also grow on sandy soils and clay soils where its roots are often waterlogged.

Table 27. Varieties of Eggplant

Variety	Maturity (DAT)
Domino F1	47
Casino F1	58
Jackpot F1	60
Bulakeña	60
Batangas long purple	70
Dumaguete long purple	60 – 70
Bulacan long purple	60 – 70
Nueva Ecija green	50 – 60
Mestiza	50 – 60
Tanauan KS	90
Llamado	70
Claveria KS	90



Eggplant fruit colors (top row) and shapes (bottom row)

Table 28. Growth stages of Eggplant

Growth Stage	No. of Days
Seeding	25 – 30 Days After Sowing (DAS)
Recovery	5 – 7 Days After Transplanting (DAT)
Vegetative	25 – 30 DAT
Flowering	35 – 45 DAT
Fruiting	45 – 55 DAT
Maturity	50 – 60 DAT

c. Seedling Production

About 250 g of seeds is required in one hectare eggplant production. Prepare soil mix (generally 2:1:1 soil: sand: compost). Sterilize mixture by drenching boiling water or burning rice hull on the bed. Allow the soil to cool off before sowing. Sow seeds at the rate of approximately five seeds per linear centimeter or ten grams of seeds per square meter and cover lightly with soil.

d. Land preparation

The field should be prepared very well. It should be pulverized and leveled. If the soil pH is lower than 5.8, apply lime one month before transplanting at the rate of 1,000 – 3,000 kilograms per hectare depending on the actual acidity of the soil.

e. Transplanting

Three weeks after pricking, transfer the seedlings into the field at a distance of 1.2 m between rows and 40 cm between plants. Carefully remove the seedlings from the seedbed or seedbox with the aide of trowel to minimize root injury and so that plenty of soil will adhere to the roots. Transplanting should be done during cloudy days or late afternoon to minimize wilting and hasten the recovery of the newly transplanted seedlings. Set transplant deep, the first true leaves just above the soil level. Irrigate immediately after transplanting.

Ideal Transplants

f. Fertilization

When transplanting, basal application of ten bags 14-14-14 per hectare or 25 g/hill should be applied. First sidedressing should be done 20-25 days after transplanting at the rate of two bags of 46-0-0 mixed with one bag 0-0-60 per hectare or approximately seven grams per hill of the mixture.

Eggplant responds very well to organic fertilizers. Apply compost or old manure if ever possible up to ten tons per hectare before transplanting.

g. Irrigation

For eggplant, furrow irrigation is recommended. If the rainfall is insufficient, irrigation should start immediately after transplanting and as needed afterwards. The soil must be soaked thoroughly but water logging must be avoided. Off-barring should be done ten days after transplanting to be followed by hilling-up one week later in order to protect the plants from water logging in order to ensure weed control.

h. Pest and Diseases

Fruit and shoot borer (*Leucinodes orbnalis Guenee*) is the most serious pest of eggplant attacking practically all parts of the eggplant. Other pests such as Epilachna beetle, red spider mite, leafhopper can be contacted locally.

Eggplant can be affected by many pathogens. Major diseases of eggplant in the Philippines are early blight, phomopsis, bacterial wilt, and damping-off.

i. Weeding

Eggplant is slow to establish and can not compete with aggressive weeds. Weeds also harbor damaging insects and diseases.

Weeds are controlled by physical methods. Hand weeding, cultivation, and mulching are quite common in small vegetable farms. Only shallow cultivation is necessary. Mulching with plastic mulch effectively controls weeds and reduces labor needs. Natural organic mulches, such as rice straw, will conserve moisture and add organic matter to the soil.

j. Harvesting

Harvest eggplant when the fruit is 2/3 maximum size for the variety, before fruit hardens, or when the fruit shows streak of unusual color, or about 2 weeks after fruit set. Harvesting can be done 2 or 3 times a week so the fruit will not become over-mature. More frequent harvesting can reduce damage from borers.

3. BELL PEPPER

a. Introduction

Sweet pepper or bell pepper is a nutritious vegetable that is gaining popularity throughout the world. Similar with other solanaceous crops, pepper is grown as cash crop because of its high market value. It is mainly used as ingredient in many food preparations. Sweet pepper can be grown successfully under local condition. Minimal labor and farm inputs are needed to produce this crop.

b. Climate and soil Requirements

Sweet pepper grows best in cooler areas. For best fruit quality and better yield however, planting in the months of October to February in the tropics is recommended. Sweet pepper can be grown throughout the year. Choose an area with dependable irrigation facilities and good drainage. The soil texture should be sandy loam or clay loam and the pH should range from 5.5 – 6.8.

Table 29. Varieties of Bell Pepper

Variety	Maturity (DAT)
Majesty F1	55
Bless F1	60
All season F1	60 – 65
Trinity F1	55 – 60
Sinagtala	60
California wonder	60
Yelo wonder	60
Lamuyo	60

Table 30. Growth Stages of Bell Pepper

Growth Stages	No. of Days
Seedling	25 – 30 Days After Sowing (DAS)
Recovery	5 – 7 Days After Transplanting
Vegetative	25 – 30 DAT
Flowering	37 – 45 DAT
Fruiting	45 – 55 DAT
Harvesting/Maturity	55 – 65 DAT

c. Seedling Production

One hectare requires 100-200 g of bell pepper seeds. It is best to produce seedlings in nurseries and transplant 3-4 weeks later. Prepare seedbeds by incorporating 2-4 kg of manure and 1-2 kg carbonized rice hull per square meter. Prepare 1-m wide beds at any convenient length. Water first then, make lines across the bed at 7-10 cm apart. Sow the seeds thinly and cover lightly with manure and mulch with rice hull. If the seedlings have been grown in shade, harden them off by gradually exposing them to direct sunlight over 4-5 days prior to transplanting.

d. Land Preparation

Plow the field once and harrow twice. Construct the furrows at row spacing of 75 cm. For small areas, make plot .75 m - 1m wide for two-row planting for every plot.

e. Planting

Irrigate the furrows during transplanting. Transplant 25-30 day old seedlings with a distance of 30-50 m between hills and 0.5-0.75 between rows. Depth of planting should be 4-6 cm depending on the height of seedlings. Plant missing hills five days after transplanting.

f. Fertilization

Amount of fertilizer to be applied depends on soil fertility recovery rate and the soil organic matter. Test the soil to determine the amount of NPK required. Forty percent (40%) of the N should be applied as basal fertilizer before transplanting. The remaining sixty percent (60%) should be side-dresses in three equal amounts at 2, 4, and 6 weeks after transplanting. Fifty percent (50%) of the P and K should be applied as basal fertilizer, and the remaining 50% should be side-dressed at 4 weeks after transplanting.

g. Mulching

Mulching is recommended to reduce weed competition, soil compaction and soil erosion to maintain a uniform root environment and to conserve soil moisture. Rice hull, rice straw or plastic may be used. In the case of plastic mulch, make beds 1 m wide and incorporate the required manure and fertilizer. Spread the mulch, covering the sides with soil. Make holes 50 cm x 50 cm apart.

h. Irrigation

Sweet peppers are fairly shallow-rooted and have low tolerance to drought or flooding. They will generally wilt and die if they stand in water for very long period so drain fields quickly after rain.

i. Pests and Diseases

Common pest of sweet pepper are aphids, spider mites, cutworm, fruitfly and fruit and shoot borer.

Diseases attacking this crop include bacterial wilt, anthracnose, leaf spot, nematodes and viral diseases.

j. Weeding

To suppress the growth of weeds, off-barring at 14-21 days after transplanting and hilling-up at 28 DAT is recommended. Spot weeding can also be done as the need arises.

k. Harvesting

Sweet peppers should be harvested when fruits reach full size (depending on variety, market, and environment) when it reaches the breaker or mature green stage or when it becomes firm. Do not wait for the fruits to ripen. Stems of pepper plants are very fragile, so use knife to harvest fruits. Sort the fruits according to market standard and separate damaged fruits.

F. OTHER VEGETABLE CROPS

1. OKRA *Abelmoschus esculentus*

a. Introduction

Okra (*Abelmoschus esculentus L.*), thought to be of African origin, was brought to the United states three centuries ago by African slaves. The word, derived from the West African *nkruma*, was in use by the late 1700s. Grown in tropical and warm temperate climates, it is in the same family as the hibiscus and cotton plants.

Okra is an erect, stout, annual herb averaging 1.5 m in height. The leaves are spreading and are spirally arranged with yellow solitary flower in leaf axils. The fruit is a cylindrical or pyramidal capsule usually green, greenish-purple or completely purple when young, and brownish when mature. Okra is mainly grown for its young immature fruits which are consumed raw, cooked or fried. The fruits can also be dried or pickled.

b. Climate and Soil Requirements

Okra is a tropical plant requiring warm growing conditions. Minimum soil temperature for germination is 15^oC. Optimum soil temperature range is 24-32^oC.

Well-drained, sandy soils are preferred. Addition of manure or other organic material is usually beneficial on such light-textured soils. Okra grows best in neutral to slightly alkaline soils with the pH of 6.5-7.5.

Table 31. Varieties of Okra

Variety	Maturity (DAS)
Smooth green	120 DAS
4025B	120 DAS
Better Five/Takii	120 DAS
Early five	100 – 110 DAS
Kaneko F1	120DAS
Greeny F1	120 DAS
Blue sky F1	120 DAS

Table 32. Growth Stages of Okra

Growth stages	**No. of Days**
Seeding	10 – 15 Days After Sowing (DAS)
Vegetative	15 – 35 DAS
Flowering	35 – 65 DAS
Fruiting/Harvesting	65 – 90 DAS
Maturity/Harvesting	95 – 120 DAS

c. Planting

Plant okra by direct seeding. Soak the seeds overnight for uniform germination and good stand. Sow two to three seeds 2 – 5 cm deep with a distance of 20 cm between plants and 25 cm between rows. Retain a maximum of two plants per hill after thinning.

d. Fertilization

The use of compost or farmyard manure together with commercial fertilizer is highly recommended. Apply 1 kg/1 m^2 land area together with complete fertilizer (14-14-14) at 10g/plant during planting time. Side-dress urea (46 –0-0) one month after planting at the rate of 10g/hill.

e. Irrigation

Okra requires adequate soil moisture throughout its entire growing period if optimum growth and yield are to be obtained. Water the crop regularly. Use furrow irrigation, if available every 7-14 days depending on season and soil type.

f. Weeding

Cultivate as often as necessary when weeds are small. Proper cultivation, field selection and rotation can reduce or eliminate the need for chemical weed control.

g. Harvesting

Okra pods should be harvested while still tender and before the seeds are half grown. This is usually 5-6 days after flowering. The pods should be gathered everyday. Regular picking increases yield. They are usually hand-picked and sharp knives are used to cut them from the stalks to avoid fruit damage like bruises and discoloration.

Sources:

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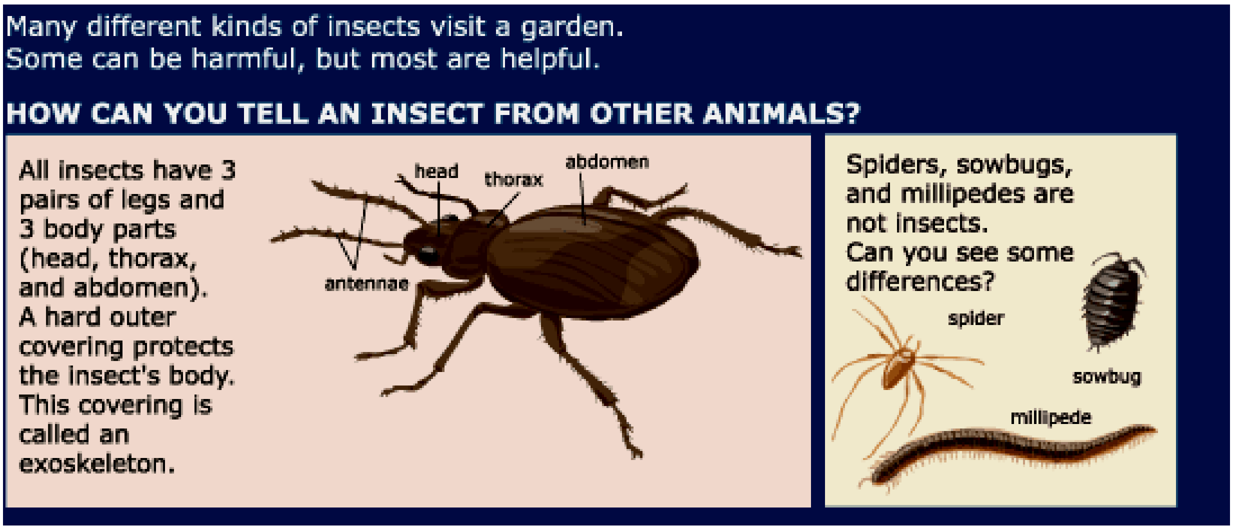
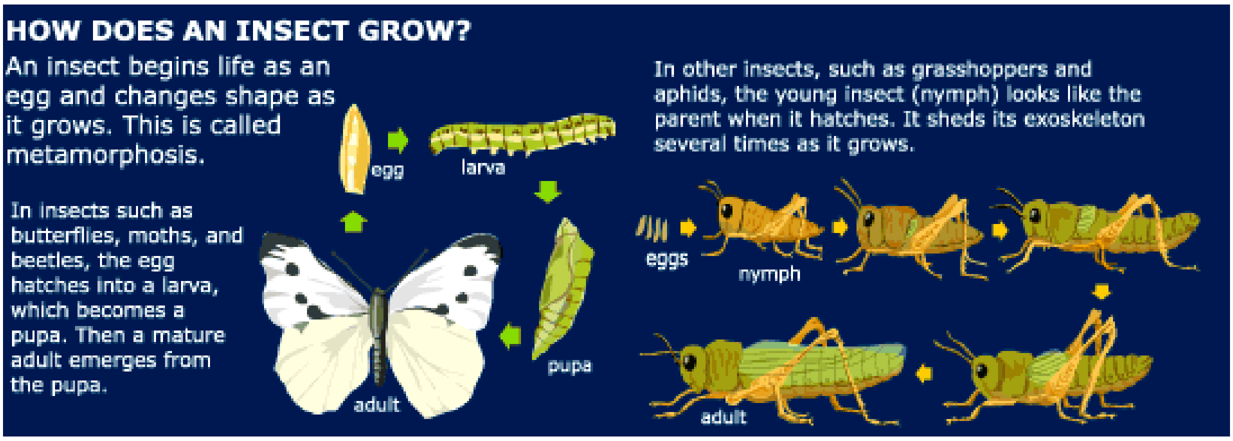
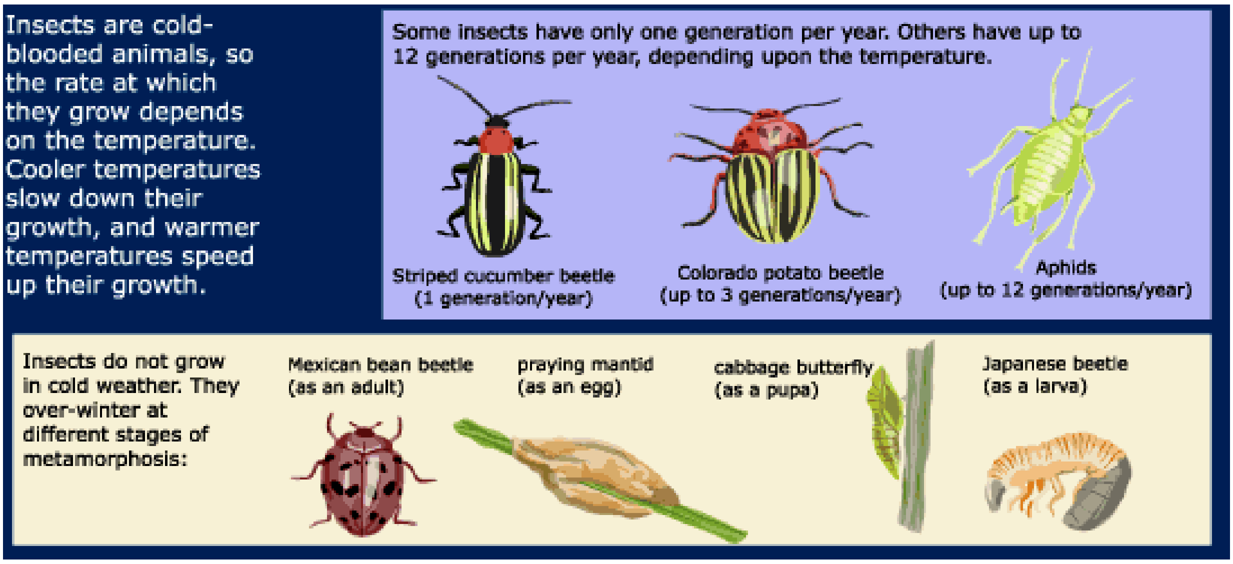
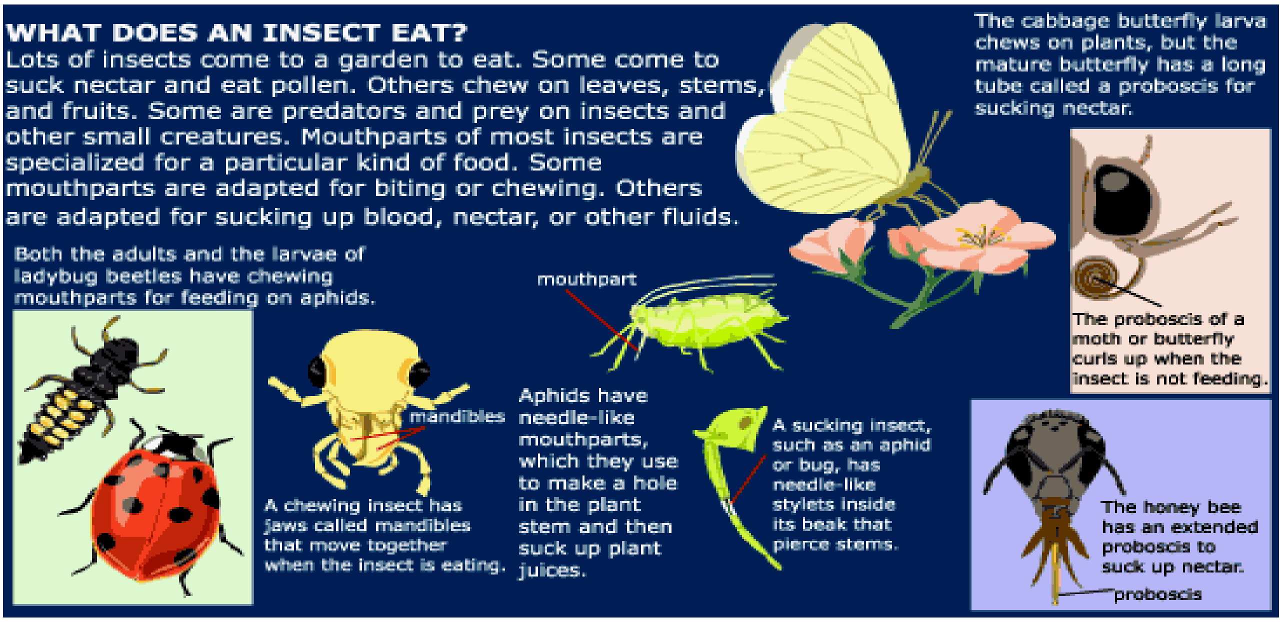
PART VII: COMMON PESTS OF VEGETABLE CROPS AND THEIR MANAGMENT

Insects and Their Characteristics









A. INSECT PESTS OF VEGETABLE CROPS

1. Aphids

Family: Aphididae

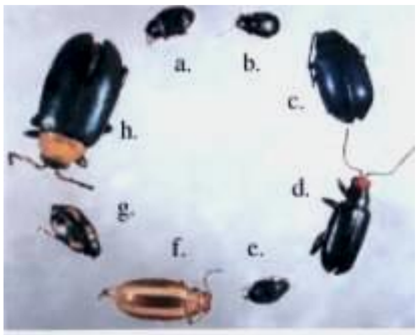
Plants attacked: Most vegetables

Type of damage: Aphids suck plant juices, may inject toxins into the plant, secrete a sticky substance called "honeydew," or transmit certain plant viruses.

Remember: Alpids are usually found in colonies on the underside of leaves. They may be winged but are usually wingless. Aphids are capable of rapidly increasing in numbers. Lady beetles and lacewings are effective predators of aphids.

2. Flea Beetles

Family: Chrysomelidae



Plants attacked: Many vegetables, especially crucifers (cabbage, broccoli, etc.) and solanaceous crops (tomato, potato, eggplant, etc.)
.
Type of damage: Flea beetles eat leaves and create

small holes in leaves. The damage can be particularly serious on small plants. The corn flea beetle can transmit a bacterium that causes Stewart's wilt on sweet corn.

Characteristics: Flea beetles come in various sizes and colors, but they all have enlarged hind legs that allow them to jump like a flea when disturbed.

3. White Grubs

Family: Scarabaeidae

Plants attacked: Most vegetables

Type of damage: Grubs feed on the roots or other underground parts of most vegetables. Damage typically consists of surface scars and round gouges.

Characteristics: Grubs are mostly a problem in fields following sod. Weedy gardens are also attractive to ovipositing beetles.

4. Leafhoppers

Family: Cicadellidae

Plants attacked: Many vegetables, including bean, potato, eggplant, celery, beet, and tomato.

Type of damage: Leafhoppers suck plant juices from the underside of leaves. Potato leafhoppers may cause a condition called "tipburn" or "hopperburn" on bean, potato, eggplant, and rhubarb. Beet leafhoppers transmit a disease called "curly top" to beet.

Remember: Leafhoppers can increase to extremely large numbers in a short time, but generally are very susceptible to insecticides.

5. Japanese Beetle

Popilia japonica,

Family: Scarabaeidae

Plants attacked: Many vegetables, fruits, field crops, ornamentals and turf grass.

Type of damage: Larvae feed on roots of turf grass and other plants. Adults feed on leaves, flowers, and fruit of many types of plants.

Remember: Adults are not effectively controlled with scented traps.

6. Cutworms

Family: Noctuidae

Plants attacked: Nearly all vegetables

Type of damage: The most common damage appear in young plants cut off at the soil surface. Cutworms may also climb the plant and feed on foliage and fruit

Remember: Damage can be reduced by keeping gardens free of weeds before and after vegetables are planted.

7. Tarnished Plant Bug

Lygus lineolaris

Family: Miridae

Plants attacked: Beet, chard, celery, bean, potato, cabbage, cauliflower, turnip, salsify, cucumber

Type of damage: Tarnished plant bugs suck plant juices and may inject toxic saliva into the plant. Leaves may become deformed, stems and petioles may be scarred and discolored, or the buds and developing fruit may be dwarfed and pitted.

Remember: Tarnished plant bugs become active very early in the season and are capable of migrating to find preferred host plants.

8. Two-spotted Spider Mite

Tetranychus urticae

Family: Tetranychidae

Plants attacked: Bean, corn, tomato, eggplant, etc.

Type of damage: Mites suck plant juices from the underside of leaves. The leaves become bronze or yellow and the foliage takes on a general wilted appearance.

Remember: Mites are not insects. The symptoms of mite damage may be caused by other factors, so be sure to look for mites with a hand lens. Mites are more of a problem in hot, dry weather, so heavy rains may help to control mites.

9. Striped Blister Beetle

Epicauta vittata

Family: Meloidae

Plants attacked: Many vegetables

Type of damage: Adults feed ravenously on foliage.

Remember: This general feeder readily moves from plant to plant. The beetles can be picked off the foliage. However, they contain an oil that can blister the skin if they are accidentally crushed. The larvae of blister beetles are beneficial because they feed on grasshopper eggs in the soil.

10. Wireworms

Family: Elateridae

Plants attacked: Many vegetables

Type of damage: Wireworms feed on seeds and seedlings of corn, bean, and pea. They also cause wilting and often death of the plant. Wireworms feed on the marketable portions of potato, sweet potato, radish, carrot, rutabaga, and turnip. Wireworms also attack the roots of cabbage, cucumber, tomato, onion, watermelon, and other crops thus, reducing vigor or killing the plants.

Remember: Some species are more serious in gardens that are recently sodded. Wireworms can be detected with baits (grain or potato) buried underground before planting.

11. Imported Cabbageworm

Pieris rapae

Family: Pieridae

Plants attacked: Cabbage, cauliflower, broccoli, Brussels sprouts, radish, collard, mustard and kale

Type of damage: Caterpillars eat leaves producing large irregular holes in leaves and into heads. Cabbageworms stunt the growth of the plants. They cause failure of the heads to form, thus making the produce totally unusable.

Remember: The adult is a common white butterfly with black spots and wing tips.

12. Cabbage Looper

Trichoplusia ni

Family: Noctuidae

Plants attacked: Cabbage, cauliflower, broccoli, brussels sprouts, radish, collard, mustard, kale, lettuce, celery, spinach, beet, pea, potatoes, tomato.

Type of damage: Same as imported cabbage worm.

Remember: Effects of Cabbage loopers are usually more serious in the fall. They should be controlled when they are still small because the large loopers are difficult to control. They crawl in a looping fashion - "inchworm."

13. Diamondback Moth

Plutella xylostella

Plants attacked: Cabbage, cauliflower, broccoli, Brussels sprouts, radish, collard, mustard, kale

Type of damage: Larvae eat many small holes on underside of leaves, giving plant a shot-hole appearance. Some feeding does not go entirely through the leaf.

14. Colorado Potato Beetle

Leptinotarsa decemlineata,
Family: Chrysomelidae

Plants attacked: Potato, tomato, eggplant, pepper

Type of damage: Adults and larvae feed on leaves and terminals, causing reduced growth or death of the plant.

Remember: Damage can be reduced by fall tillage and elimination of culls and volunteer potato plants. Applying 4-6 inches of straw mulch just after hilling will reduce potato beetle damage.

15. Hornworms

Manduca spp.

Family: Sphingidae

Plants attacked: Tomato, potato, pepper, eggplant

Type of damage: The tomato and tobacco hornworms consume large amounts of green foliage and sometimes fruit.

Comments: Easily detected through presence of droppings resembling those produced by rabbits. Can be controlled in home gardens by hand picking. Many hornworms are killed by parasites that pupate on the hornworm's body.

16. Corn Earworm or Tomato Fruitworm

Helicoverpa zea

Family: Noctuidae

Plants attacked: Many, including corn, tomato, bean, pepper, okra, eggplant

Type of damage: Corn earworms feed on the marketable portion of each vegetable crop that it attacks, often making them unusable.

Remember: Home gardeners may wish to cut the damaged tips off sweet corn ears or plant extra to compensate for losses.

17. Striped Cucumber Beetle

Acalymma vittatum

Family: Chrysomelidae

Plants attacked: Cucurbits (cucumber, cantaloupe, squash, gourd, pumpkin, watermelon)

Type of damage: Larvae feed on roots and underground stems. Adults may destroy newly emerged plants. On older plants, beetles feed on leaves, shoots, and stems. The beetles transmit a bacterium that causes bacterial wilt to cucumber and cantaloupe.

Remember: Only a short period of feeding is necessary to transmit the bacterium, so plants must be protected from beetle feeding. Protecting plants with row covers before bloom will prevent beetle feeding and disease transmission, but be sure to remove them when flowers appear.

18. Spotted Cucumber Beetle

Diabrotica undecimpunctata howardi

Family: Chrysomelidae

Plants attacked: Cucurbits, bean, pea, potato, beet, asparagus, eggplant, tomato, corn, cabbage

Type of damage: Larvae feed on roots of corn, beans, alfalfa, and many grasses. Adults feed on foliage and also transmit bacterial wilt of cucurbits to cucumber and cantaloupe.

19. Squash Bug

Anasa tristis

Family: Coreidae

Plants attacked: All cucurbits, but especially squash and pumpkin

Type of attack: Nymphs and adults suck plant juices causing leaves to wilt and die. They also feed on developing fruit and may also transmit a disease organism that causes yellow vine.

Remember: Squash bugs are usually found in colonies. Destroying crop refuse may reduce the number of squash bugs over winter and lessen problems the following year.

20. Squash Vine Borer

Melittia cucurbitae

Family: Sesiidae

Plants attacked: Squash, pumpkin, gourd, cucumber

Type of damage: Larvae bore into the vine, causing a sudden wilting of a vine or an entire plant.

Remember: Plants need to be protected with insecticides or screens when vines begin to run. Once inside the vine, the borers are impervious to insecticides.

21. Bean Leaf Beetle

Cerotoma trifurcata

Family: Chrysomelidae

Plants attacked: Bean, pea, soybean

Type of damage: Larvae feed on roots, nodules, and underground portions of the stem. Adults feed on stems of seedlings and chew round holes in leaves and pods.

Remember: Plants can usually tolerate a considerable amount of leaf feeding.

22. Mexican Bean Beetle

Epilachna varivestis

Family: Coccinellidae

Plants attacked: Bean, cowpea, soybean

Type of damage: Larvae and adults feed on the undersurface of the leaves, giving them a lacy appearance. They may also attack pods when abundant.

Remember: Heavy rains help by knocking adults and larvae off the plants.

23. Corn Borer

Ostrinia nubilalis

Family: Pyralidae

Plants attacked: Corn, pepper, bean, tomato

Type of damage: Larvae feed on foliage and ears of corn, bore inside pepper and tomato fruit, and feed on or bore into bean pods.

Comments: Damage to corn may be serious enough to require insecticide treatments, especially late in the summer. On the other hand, damage to pepper, tomato, and bean can usually be tolerated by home gardeners.

B. NATURAL ENEMIES OF INSECT PESTS OF VEGETABLES

<u>Friendly Insects</u>

Assassin bug (*Reduviidaye)*- Assassin bugs are killer insects that eat other bugs. They lie in wait for insects and then stab the prey with their proboscis (the beak) and inject a toxin that dissolves tissue. The assassin bug then sucks up the other bug's tissues. Sometimes, when other food is not available, assassin bugs even eat each other.

Like all insects, they have 6 jointed legs, two antennae, and an exoskeleton made of chitin (a material that also forms our hair and fingernails). Their three-part body consists of a head (with the mouthparts, eyes, and antennae), thorax (where the legs and wings attach), and the abdomen (with the reproductive, and most digestive organs).

Damsel Bug (*Nabidae)* – Damsel bugs are important predators that feed on plant pests such as aphids, beetle larvae, caterpillars and other soft-bodied insects. Damsel bugs are dull brown with light and dark markings. They are more elongated than other bugs and have thickened forelegs for grasping prey. They also have fairly long antennae.

Big-eyed bug (*Lygaedae)* –Big-eyed bugs have oval bodies and broad heads with distinctive, wide-set, bulging eyes. They have short antennae with an enlarged tip. Adults are usually gray, brown or yellowish in color.They stalk their prey which include caterpillars, lygus eggs and nymphs; aphids, spider mites, flea beetles, caterpillar eggs and larvae; and immature bugs, and leafhoppers.

Predacious stink bug (*Pentatomidae)* – Predacios stink bugs feed on Colorado potato beetles and various caterpillar larvae.

Syrphid fly larvae (*Syrphidae)* – Fly larvae of this species feed on aphids and other soft-bodied insects, such as mealybugs and spider mites.

Lady Beetle (*Hippodamia convergens)* – The lady beetle feeds mainly on aphids and other soft-bodied insects, such as mealybugs and spider mites.

Green lacewing larvae (*Chrysopa carnea)* – Lacewing larvae, known as aphid lions, feed on insect eggs, aphids, spider mites, thrips, leafhopper nymphs, and small caterpillar larvae. Adult lacewings are not predacious.

Predatory mites (*Phytoseiulus persimilus)*- Predatory mites and several other species feed on many mite pests, including the two-spotted spider mites.

Trichogramma wasp (*Trichogrammatidae)* –tiny wasps attack eggs of more than 200 pest species, including cutworms, corn borers, corn earworms, armyworms, coding moths, and cabbage moths. The release time of trichogramma wasps is critical for their effectiveness since they only attack pest eggs.

Encarsia Formosa (*Encyrtidae)* – The greenhouse whitefly is parasitized by this wasp in third and fourth larval instars when Encarsia Formosas lay their eggs inside the whitefly scale.

PREDATORY ARTHROPODS

Arthropod predators make up the most numerous and widely diverse group of natural enemies of insects associated with vegetable and soybean. Many species of predators are active only at night while others actively search the foliage of crops during the day. Most predators feed on a wide variety of insects but some are quite specific. Generalist predators make up the most important group of natural enemies in most cultivated crops and are seriously affected by chemical insecticides.

Name: *Paederus fuscipes* Curtis
Family: Staphylinidae
Order: Coleoptera

The small (10mm) red and black beetle is common in all cultivated ecosystems in the tropics and feeds on eggs and other soft-bodied insects. It moves quickly over the foliage and often drops from the plants when disturbed.

Name: *Philonthus sp.*
Family: Staphylinidae
Order: Coleoptera
The staphylinid is larger (12-14 mm), less abundant and less colorful than *Paederus fuscipes*.

Ladybeetles are abundant members of the community of predatory insects that are common to vegetable and soybean fields in Southeast Asia. With few exceptions, adults and larvae are predaceous. There are a number of species that can be identified by their distinct color patterns. However, color patterns may be quite variable in some groups. Ladybeetles feed on aphids, eggs of lepidopterans and other small soft-bodied insects. They may also use pollen and nectar as sources of energy.

Name: *Micraspis lineate* (Thunberg)
Family: Coccinellidae
Order: Coleoptera
This brightly colored orange and black ladybeetle (5 mm) can be abundant in soybean and mungbean. They are often seen feeding on nectarines of mungbean.

Name: *Coccinella transversalis* F.
Family: Coccinellidae
Order: Coleoptera

The larvae within this group are brightly colored yellow and black. Members of this group are larger than *Micraspis, h*owever, the behavior and biology of both genera are quite similar. Color patterns may be somewhat variable as with many other ladybeetles.

Name: *Cheilomenes sexmaculatus* (F.)
Family: Coccinelidae
Order: Coleoptera
These coccinellids are pink and black in color. The Adults and larvae feed voraciously on aphids in soybeans. Pupation takes place on the plant, usually on the undersides of the leaves.

Name: Harmonia octomaculata F.
Family: Coccinellidae
Order: Coleoptera
As with many ladybettles, this species may have more than one color pattern.

Name: *Coleophora inequalis* (Thunberg)
Family: Coccinellidae
Order: Coleoptera
This is another representative of the large and diverse group of ladybeetles that inhabit vegetable and soybean fields. Little is known about its biology and behavior.

Name: *Calleida* sp.
Family: Carabidae
Order: Coleoptera

Ground beetles are members of the family Carabidae. They are swift runners and move rapidly over the plants and soil surface, especially at night when they are in search of suitable prey. Often, these predatory beetles attack prey much larger than themselves. Picture above shows *Calleida* sp. feeding on a larva *of Spodoptera litura*. Both larvae and adults are predatory. *Chlaenius bimaculatus* (Dejean) is shown feeding on a larva of *Spodoptera exigua*. Lepidopteran larvae and eggs together with eggs of sucking bugs make up a large part of the diet of carabid beetles. Because many of the Lepidoptera do not exist in numbers high enough to cause yield or quality losses, they are often valuable sources of food for supporting populations of carabid beetles and other predators, which may latter attack more important pest species.


Name: *Ophionea interstitialis* Schmidt-Goebel
Family: Carabidae
Order: Coleoptera
The brightly colored carabid attacks a range of prey and moves rapidly about the foliage during day-light hours. Its prey is similar to that of other small carabids, e.g., small soft-bodied insects and their eggs.

Name: *Formicornus* sp. or ant beetle
Family: Anthicidae
Order: Coleoptera
This tiny black beetle could easily be mistaken for an ant. It feeds on soft-bodied insects and eggs of several moths. Little is known about the biology and behavior of this beetle.

Name: *Metioche* sp. Predatory cricket
Family: Gryllidae
Order: Orthoptera
Metioche is one of the most common cricket predators in vegetables and soybeans. It also thrives in rice planted in rotation with vegetables and soybeans. As an excellent egg predator it is often not recognized as a beneficial insect.

Name: *Preying mantis*
Family: Mantidae
Order: Mantodea
Several species of preying manties are found in vegetables and soybeans. They do not normally actively search for their prey but remain stationary until suitable prey comes near enough to be attacked and captured.

Name: *Chrysoperla* sp.
Family: Chrysopidae
Order: Neuroptera

Chrysoperla lay their eggs on stalks and on the upper surface of the leaves. The larvae have well-developed mouth parts for catching and consuming prey. Larval development takes only about two weeks. Adults are light green in color and have net-like wings folded like a tent over the body. When disturbed, the adults produce a strong odor.

Name: *Andrallus spinidens* (F.)
Family: Pentatomidae
Order: Hemiptera
Andrallus spinidens is an impressive predatory sucking bug that is capable of attacking and killing large caterpillars. The eggs of this predator are often parasitized by small wasps.

Name: *Eocanthecona furcellata* (Wolff)
Family: Pentatomidae
Order: Hemiptera
This predatory stink bug is not as common as *Andrallus spinidens*, but its behavior in capturing prey is similar to that of *A. spinidens*.

Name: *Pygomenida varipennis* (Westwood)
Family: Pentatomidae
Order: Hemiptera
This small pentatomid acts mainly as a predator of eggs and young butterflies and moth larvae. It also may suck juices from plants. However, this does not damage the plant itself.

Name: *Rhynocoris* sp.
Family: Reduviidae
Order: Hemiptera
This small to medium-sized predator is not abundant but contributes to a group of predators that kill their prey by inserting their mouthpart and injecting toxin into the prey. It paralyzes the prey and makes it easy for the predator to suck out the liquid contents of its victim.

Name: *Sycanus* sp.
Family: Reduviidae
Order: Hemiptera
This large (18-20 mm) predator is capable of successfully attacking large larvae such as members of the hawk moth family *Spingidae*. It lays its eggs together in a mass held together by a sticky material.

Name: *Ectrychotes* sp.
Family: Reduviidae
Order: Hemiptera

This colorful predatory bug is quite large (about 15 mm) but not usually abundant.

Name: *Chrysosoma* sp.
Family: Dolichopodidae
Order: Diptera
These predatory flies are referred to as long-legged flies or dance flies. Most are brightly colored, usually metallic green or gold. The adults prey on small insects such as whiteflies and leafhoppers.

Name: Robber fly
Family: Asilidae
Order: Diptera
These fast flying predatory flies are capable of attacking a wide variety of insects.

Name: *Ischiodon scutellaris* (F.)
Family: Syrphidae
Order: Diptera
These insects are sometimes referred to as hover flies because of the way the adults hover or fly on one spot. The larval form of syphrids is predaceous.

Name: *Ropalidia* sp.
Family: Vespidae
Order: Hymenoptera
This small predatory wasp constructs a nest that is often found attached to the undersides of soybean leaves. It is considered an important predator in soybeans because of its habit of attaching itself to the undersides of soybean leaves.

Name: *Poliste s* sp.
Family: Vespidae
Order: Hymenoptera
Polistes wasps attack a wide variety of caterpillars in almost all vegetable and soybean crops.
Name: *Vespa* sp.
Family: Vespidae
Order: Hymenoptera
This vespid wasp is feeding on the remains of a looper, probably *Thysanoplusia orichalcea*, in carrots. This host has been infected and killed by an insect virus. Studies have shown that predators can spread insect viruses by feeding on virus-infected hosts and later excreting the virus in other areas of the field.

Name: *Eumenes* sp.
Family: Vespidae
Order: Hymenoptera
Caterpillars make up a large part of the diet of vespid wasps. Large caterpillars are chewed up and carried away piece by piece. Caterpillars are also fed to developing larvae of predatory wasps.

Name: *Euborellia* sp.
Family: Carcinophoridae
Order: Dermaptera
Members of this order are commonly referred to as earwigs. Although some species are plant feeders, others are voracious predators. They hide in the soil or plant parts until night time when they search plants for eggs, larvae and nymphs of smaller soft-bodied insects.

SPIDERS

Spiders comprise a large and very diverse group of beneficial arthropods in vegetable crops and soybeans. Their predatory habits and abundance make them very important in controlling populations of pests and keeping them from reaching damaging levels. Their behavior in capturing prey varies with the species. Many are active at night. They actively stalk their prey while others wait for prey to come close before moving for the kill. Even though the spider fauna is rich and diverse in Southeast Asia, only a few species are presented here.

Name: *Argiope trifasciata* (Forskal)
Family: Araneidae
Order: Araneae
This adult female garden spider secures her elongated and light brown egg cocoon in the center of the web. Like other garden spiders *A. trifasciata* captures her prey using a web.

Name: *Leucauge decorata* (Blackwall)
Family: Tetragnathidae
Order: Araneae
Tetragnathid spiders catch their prey through their webs but may hunt their prey or they may lie in wait for an unsuspecting victim to pass nearby.

Name: *Marpissa* sp.
Family: Salticidae
Order: Araneae

This immature stage of jumping spiders feeds on a winged ant. It is common for predators to feed on other predators during periods when populations of plant-feeding insects are not available. This helps to maintain predator populations in the crop until potential pests arrive.

Name: *Carrhotus barbatus* (Karsch)
Family: Salticidae
Order: Araneae
Jumping spiders actively stalk their prey and do not rely on web-building for prey capture.

Name: *Siler* sp. (Figure 207)
Family: Salticidae
Order: Araneae
This shows a larva of a leaf-feeding looper being eaten by a female jumping spider. As a result, looper larvae rarely reach population levels that can cause crop losses.

Name: *Crustulina* sp. (Figure 208)
Family: Theridiidae
Order: Araneae
This comb-footed spider is feeding on an adult leafminer fly, *Liriomyza* sp. (Diptera: Agromyzidae) captured earlier on bean leaves and held down by silken threads.

Name: *Oxyopes* sp. (Figure 209)
Family: Oxyopidae
Order: Araneae
This female lynx spider is devouring a young armyworm.

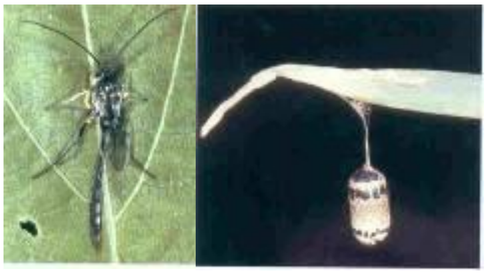
Name: *Pardosa* sp. (Figure 210)
Family: Lycosidae
Order: Araneae
These spiders are excellent hunters both on the ground and in the plant canopy. Each female produces 100 eggs in one cocoon. Females carry their young on their back. The females chew the cocoon to soften it, thereby providing food for nourishment of newly- hatched spiderlings.

PARASITOIDS

Parasitoids are considered to be very important in checking populations of potential insect pests from reaching pest status. They are mostly host-specific than insect or spider predators and need only an individual host to complete their development to adulthood. Often, more than one parasitoid can develop and emerge from a single host. In general, parasitoids are much more sensitive to pesticides than are predators.

Name: *Eurytoma* sp. (Figure 211)
Family: Eurytomidae
Order: Hymenoptera
This eurytomid wasp (*Eurytoma* sp.) is a common inhabitant of pepper pods. It is parasitic on *Asphondylia* sp., an occasional pest of chili peppers.

Name: *Charops brachypterum (Gupta)* and Maheswary
Family: Ichneumonidae
Order: Hymenoptera
This male ichneumonid wasp is resting on a leaf after emerging from its oblong cocoon. It is distinguished by the black elongated abdomen, and yellow front and middle pair of legs. The pupal cocoon is shown hanging from an onion leaf.



Name: *Diadegma semiclausum* (Hellen)
Family: Ichneumonidae
Order: Hymenoptera
This parasitoid plays a major role in suppressing populations of the diamondback moth in crucifers.

Name: *Diadromus collaris* (Gravenhorst)
Family: Ichneumonidae
Order: Hymenoptera
This parasitoid attacks the pupae of the diamondback moth. It complements the action of the larval parasitoid, *D. semiclausum*.

Name: *Eriborus argenteopilosus* (C ameron)
Family: Ichneumonidae
Order: Hymenoptera
This ichneumonid wasp is one of the most common parasitoids of *Spodoptera exigua* in shallots and leaf onion. An adult female *Eriborus argenteopilosus* (Cameron) is shown in Figure 218. The parasitoid is characterized by the red posterior portion of abdomen, yellow base of antennae and black basal one-third to one-half femur and tibia of hind legs. Populations of this parasitoid are often kept low by the heavy use of chemical pesticides.

Name: *Colpotrichia* sp.
Family: Ichneumonidae
Order: Hymenoptera
The stout-legged wasp is a larval parasitoid of cabbage webworm or *Crocidolomia binotalis*. It is distinguished from related parasitoids by the presence of stout and uniformly yellow legs.

Name: *Temelucha etiellae* Kusegimati
Family: Ichneumonidae
Order: Hymenoptera
This parasitoid is a common species that attacks the soybean pod borer, *Etiella* spp. The cocoon is brown and covered with silk. The level of parasitism, however, is usually low.

Name: *Enicospilus* sp.
Family: Ichneumonidae
Order: Hymenoptera
This large (about 18 mm) ichneumonid emerges from a looper, *Chrysodeixis* sp., on soybean.

Name: *Baeognatha javana* Bhat and Gupta
Family: Braconidae
Order: Hymenoptera
This female braconid parasitoid attacks larvae of *Etiella* spp., an important pest of soybean. The parasitoid is characterized by the red thorax and black abdomen with white on its sides.

Name: *Mycroplitis similis* (Lyle)
Family: Braconidae
Order: Hymenoptera
This small black parasitic wasp is one of the most common species attacking *Spodoptera litura* a mature larva of *M. similes*.

Name: *Euplectrus* sp.
Family: Eulophidae
Order: Hymenoptera
These parasitoids are shown attached to a host larva, *Spodoptera litura*. The adult parasitoid lays its eggs on the outside of the host's body. Hatching larvae attach themselves to their hosts by using their mouth hooks. They pupate in cocoons against the body of the dead host.

Name: *Glyptapanteles phytometrae* (Wilkinson)
Family: Braconidae
Order: Hymenoptera
This braconid parasitoid emerges from its looper host, *Chrysodeixis chalcites*. A pupal cocoon is shown beside its dead host larva on a soybean leaf.

Name: *Cotesia* sp.
Family: Braconidae
Order: Hymenoptera
Parasitoids in this genus attack several host species. The pictures show newly formed pupal cocoons around and underneath the dead host larva of the soybean leaffolder, *Omiodes indicata*. *Chrysodeixis chalcites* is also a host for this group of parasitoids as is *Thysanoplusia orichalcea* and the lymantriid, *Orgyia* sp.

Name: *Cotesia plutellae or* Kurdjumov cocoon
Family: Braconidae
Order: Hymenoptera
This parasitoid attacks the diamondback moth on crucifer crops. It is especially important in the lowlands where *Diadegema semiclausum* may not be as effective. A cocoon is shown here

beside a dead larva.

Name: *Biosteres longicaudatus* Ashmead
Family: Braconidae
Order: Hymenoptera
The adult female of this braconid wasp is ovipositing on its host, the larva of the oriental fruit fly, *Bactocera dorsalis* (Hendel).

Name: *Opius* sp.
Family: Braconidae
Order: Hymenoptera
This is one of the several species that attacks the soybean leaffolder, *Omiodes indicata* and the pod borer, *Maruca vitrata*. Parasitism rates however, are not usually high.

Name: *Phanerotoma philippinensis* (Ashmead)
Family: Braconidae
Order: Hymenoptera
This is one of several parasitoids that attack *Etiella* spp. in soybean. Also, it parasitizes *Maruca vitrata* (*testulasis*), a pest of longbean.

Name: *Copidosomopsis truncatella* Dalman
Family: Encyrtidae
Order: Hymenoptera
The egg stage of the host is attacked by this parasitoid. Even after being parasitized, the egg of the host hatches normally and the developing parasitoid egg divides many times as the host grows. Shortly before the host larva pupates, a mummified host larva is produced. Several hundred adult parasitoids emerge from a single mummified host larva.

Name: *Argyrophylax* sp.
Family: Tachinidae
Order: Diptera
This tachinid parasitoid is searching for its host on a leaf surface. Parasitism by tachinids is usually low.

Name: *Palexorista* sp.
Family: Tachinidae
Order: Diptera
This tachinid fly is a common parasitoid of *Sodoptera* spp.

Name: Tachinid eggs
Family: Tachinidae
Order: Diptera
This *Spodoptera exigua* larva has been parasitized by a tachinid fly. The white tachinid eggs are clearly visible on the side of the host larva.

INSECT DISEASES

Fungi

In most locations in Southeast Asia, weather conditions are ideal for the development of fungi, so that insects and other arthropods can be infected by a wide variety of fungal pathogens. Since most fungi produce extensive growth on the external surface of their hosts, symptoms of their infection are more striking and easily recognized. Fungi are probably reported as natural enemies more frequently than other pathogen groups such as viruses and protozoas.

Most fungal pathogens including all reported here, can be divided into two main groups, the Entomophthorales (Zygomycotina) and the Hyphomycetes (Deuteromycotina). The defining characteristic of entomophthorales is the production of conidia which are forcibly ejected from the host onto the surrounding substrate. On the other hand, hyphomycetes, also called imperfect fungi, usually form an extensive layer of vegetative growth (mycelium) on the outside of the host. Conidia are produced on the surface of this mycelium and are not forcibly ejected.

Entomophthorales

The Entomophthorales are a large group of fungi important in regulating agents in insect populations. They are able to spread rapidly through a population and cause extensive mortality, especially when host insect populations are high. Some species are quite host-specific and can be identified by their association with a certain host, but others have been reported from a wide range of hosts, even from different orders. There are about ten genera which are identified mainly by characteristics of the primary and secondary spores.

Name: *Erynia* sp.
Family: Entomophthorales
Host pictured: *Crocidolomia binotalis*
Host range: Unknown
Description: External growth on the larva is white to light tan. Spores that are white and oval are produced in large numbers on the surface of this hyphal mat. *Erynia* sp. is found in moist upland areas and is only found in low incidence.

Name: *Pandora gammae* (Weiser) Humber
Family: Entomophthorales

Host pictured: *Thysanoplusia orichalcea*
Host range: Loopers in the subfamily Plusiinae

Description: Infected larvae climb to the tops of the plants and attach by their prolegs before they die. The larvae die in the late afternoon and sporulation occurs throughout the night. Spores are white and oval. A freshly killed larva has a very fine growth of light tan colored hyphae over the entire surface with tufts of longer white hyphae emerging from the ventral surface. As sporulation progresses, the color changes to brown and then dark brown and the cadaver becomes wrinkled and collapsed. At this stage the cadaver resembles that of a virus-killed larva, but can be distinguished by the masses of white spores clinging to the setae. This fungus is an important regulating agent in looper populations. It can cause extensive mortality when larval populations are high.

Name: *Entomophaga grylli* (Fresenius) Batko
Host pictured: grasshopper [*Ailophus thalassinus tamulus* (F.)]
Host range: Most grasshopper species

Description: Infected grasshoppers cling to upper portions of plants before they die. Clumps of spore-producing hyphae grow through intersegmental membranes. Spores are large, pear-shaped, and white. *E. grylli* occasionally causes extensive mortality in grasshopper populations.

Name: *Zoophthora radicans* (Brefeld) Batko
Host pictured: *Plutella xylostella*
Host range: Wide host range

Description: This fungus infects larvae, pupae, and adults of *P. xylostella*. It forms an extensive flat mat of external hyphae which grows out from both sides of the larva. Numerous white spores are formed on and ejected from this mat. Spores are elongated and spindle-shaped, with a cone-shaped point at the base and rounded at the top.

Name: *Zoophthora radicans* (Brefeld) Batko
Host pictured: Cabbage aphid
Host range: Wide host range

Description: *Z. radicans* is also a common pathogen in aphid populations. Dead aphids are attached to the leaf surface by many thin fungal structures that grow out from the lower surface of the aphid. The fungus forms a white to tan-colored hyphal mat over the top of the aphid on which numerous white spores are produced. Spores are elongated and spindle-shaped with a cone-shaped base and a rounded point.

Name: Unidentified Entomophthorales
Host pictured: *Trialeurodes vaporariorum*

Host range: Unknown
Description: This fungus infects adult whiteflies. Dead whiteflies are attached to the leaf surface by fungal structures and their wings are spread apart, exposing the abdomen on which spores are produced. Spores and hyphae are white.

Name: *Entomophaga* sp.
Host pictured: Cutworm
Host range: Unknown

Description: This fungus has been found infecting instar larvae of cutworms on cabbage in upland areas of Sumatra. Dead larvae have been found attached to the outer edges of the leaves. The fungus does not form an extensive growth on the outside of the larva. Freshly-killed larvae are brown and turn black and shrink after sporulation is complete. Spores are large, oval and white.

Hyphomycetes

The hyphomycetes or imperfect fungi are distinguished from the Entomophthorales by forming spores which are not forcibly ejected from the host. They usually form an extensive growth of hyphae on the outer surface of the host and sometimes form stalk-like structures which grow out from the host. Genera and species are usually distinguished by color, shape, and arrangement of the spores, and by the presence or absence of stalk-like structures. Hyphomycetes can usually be cultured easily on artificial media.

Name: *Nomuraea rileyi* (Farlow) Sampson
Host pictured: *Helicoverpa armigera, Spodoptera exigua* and *S. litura*
Host range: Mostly larvae of Lepidoptera

Description: Before sporulation occurs, the dead host is covered by a thick growth of white mycelium (on *Helicoverpa armigera*). When sporulation occurs, the larva turns green due to a heavy accumulation of green spores (on *Spodoptera exigua*), on *Spodoptera litura*). Spores are light green and oval.

Name: *Hirsutella* sp.
Host pictured: *Plutella xylostella*
Host range: Unknown
Description: Freshly-killed cadavers have a thin layer of mycelium with tufts forming at various locations which eventually develop into grey stalks (synnemata). Spores are clear and spindle-shaped.

Name: *Hirsutella* sp.
Host pictured: Helicoverpa armigera
Host range: Unknown

Description: The host larva is covered with tan-colored mycelium out of which several stalk-like structures (synnemata) develop. These stalks are dark grey with white tips. Spores are formed on the surface of these stalks. This fungus is not common.

Name: *Hirsutella* sp.
Host pictured: *Stenocranus bakeri*
Host range: Unknown
Description: This fungus is one of the Hirsutella species that do not form stalks. Clear spindle-shaped spores are formed along these hyphae.

Name: *Beauvenia bassiana* (Balsamo) Vuillemin
Host pictured: *Cylas formicarius*
Host range: Wide host range
Description: *B. bassiana* is characterized by having white hyphae and white spores clumped together into spore balls.

Name: *Verticillium* sp.
Host pictured: *Rhopalosiphum maidis*
Host range: Aphids, whiteflies, thrips and other insects
Description: This fungus has white hyphae and white conidia. Hosts become completely covered by the hyphae and the white cylindrical spores accumulate into slime balls on the surface of this hyphal mat.

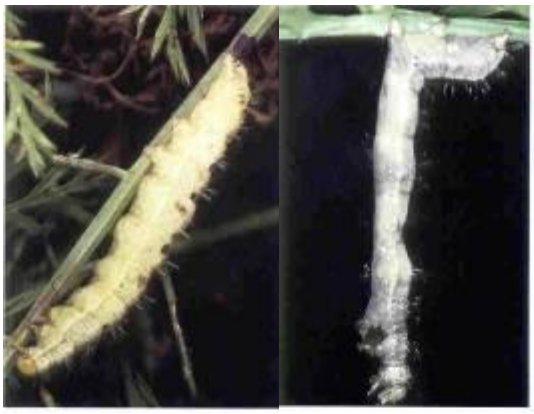
Name: *Paecilomyces* sp.
Host pictured: *Plutella xylostella*
Host range: Unknown
Description: Hyphae are white and form a thick mat over the entire host. This fungus is characterized by having stalks (synnemata) which are clubbed or enlarged at the tips. White oval spores are formed in clumps on the surface of these clubbed structures.

<u>Viruses</u>

Viruses have been isolated mostly from larvae of moths. All of the ones reported are nuclear polyhedrosis viruses (NPVs). NPVs are very effective natural regulating agents, especially when larval populations are high. These viruses can spread rapidly through populations and cause dramatic epizootics.

<u>Description:</u> In late stages of infection, larvae infected with NPV turn white and become swollen and sluggish. Just before they die, the larvae climb to the tops of the plants and attach themselves to leaves by their prolegs. After death, the larvae quickly turn brown or black, the internal contents become liquefied, and the integument becomes very fragile. The integument ruptures, releasing the liquid contents which contain millions of polyhedral bodies of the virus. If this liquid is examined with a compound microscope, the polyhedral bodies can be seen as bright refractile bodies. In the field, this virus-containing liquid is spread over the plant and is fed on by other larvae. Larvae die within 4-7 days after ingesting the virus.

NPVs for a number of caterpillar pests, including *Helicoverpa armigera* and *Spodoptera exigua*, have been developed and used successfully as microbial insecticides.



Name: *Thysanoplusia orichalcea* NPV (ThorNPV)
Host pictured: *T. orichalcea*
Host range: Several species of Plusiinae (loopers)
There are two distinct NPVs of *T. orichalcea* that can be only distinguished by examining the polyhedral bodies (PIBs) with a compound microscope. One has small pyramid-shaped PIBs and the other has large, irregular-shaped PIBs. Both cause similar symptoms in the host. The pyramid-shaped NPV is the one found most frequently in the field. It is a very effective regulating agent in looper populations, especially in carrots and potatoes. The picture below shows a live looper in the late stages of virus infection and a recently-killed larva hanging by its prolegs.

Name: *Spodopters litura* NPV (SINPV)
Host pictured: *S. litura*
This is a typical NPV with large irregular-shaped polyhedra. It is not found frequently in the field under natural conditions, but it is quite effective in reducing larval populations when applied as a microbial agent. The picture shows a virus-killed larva with the liquid contents leaking out through a break in the integument.

Name: *Spodoptera exigua* NPV (SeNPV)
Host pictured: *S. exigua*
Host range: Specific for *S. exigua*
This is a typical NPV with large irregular-shaped polyhedra.This virus is not common as a nature regulating agent, but has been very effective as microbial agent, especially in shallots in Indonesia.

Protozoa

Most protozoan pathogens reported from Lepidoptera are members of the microsporidia group. They are characterized by the production of larger numbers of spores which accumulate in the fat body and blood of the host larva. Spores in the blood can easily be seen with a compound microscope. They are oval and refractile. Externally, infected larvae turn white due to the accumulation of large numbers of spores in the tissues. At this stage, larvae appear similar to those infected by NPVs. However microsporidian disease takes longer to kill the larvae than do viruses. A larva may remain alive for 7-10 days. An NPV-infected larva that has reached the white stage usually dies within 24 hours. Also, the integument of a microsporidian-infected larva does not become fragile as with NPV infection. Because of the chronic nature of microsporidian infections, these pathogens are often overlooked in surveys for natural enemies. However, they are quite common and probably play an important role in population suppression.

Name: Microsporidian of *Spodoptera exigua*
Host pictured: *S. exigua*
Host range: Unknown
Extensive surveys for natural enemies of this pest in Indonesia, reveal that this has been the most common pathogen. Infection levels by this protozoan pathogen have been as high as 20% in some locations.

Name: Microsporidian of *Argyrogramma signata*
Host pictured: *A. signata*

Large numbers of spores in the fat body make the larva look whiter than normal. Microsporidian infections can be found in all three species of loopers (*A. signata, C. chacites and T. orichalcea*) and it may be the same pathogen infecting all three looper species.

Nematodes

Name: Mermithid nematode
Host pictured: *Helicoverpa armigera*
Host range: Unknown
Mermithids develop within their hosts until the last larval stage of the nematode is reached. They then kill their host by emerging through the cuticle. All the nematodes shown in the picture emerged from a single H. armigera larva.

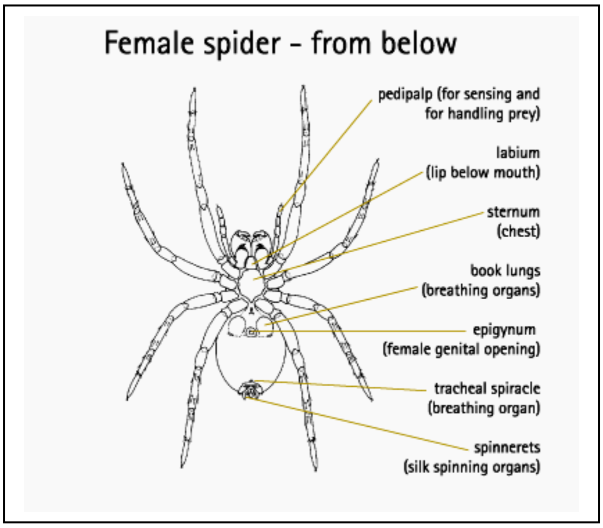
C. Spiders

What are Spiders?

Spiders are arachnids not insects, but both spiders and insects belong to the largest group of animals on Earth, the arthropods. **Anthropods** are animals with hard external skeletons and jointed limbs (greek arthro = joint, podos = footed).

What are the Differences of a Spider and Insect?

- Spiders have two main body parts, eight walking legs, simple eyes and piercing jaws (fangs), abdominal silk-spinning organs, anterior abdominal genital opening.
- Insects have three main body parts, six walking legs, compound eyes, antennae, chewing jaws (mandibles which are often secondarily modified), posterior abdominal genital opening.
- Spiders can't fly.
- Many insects can fly.



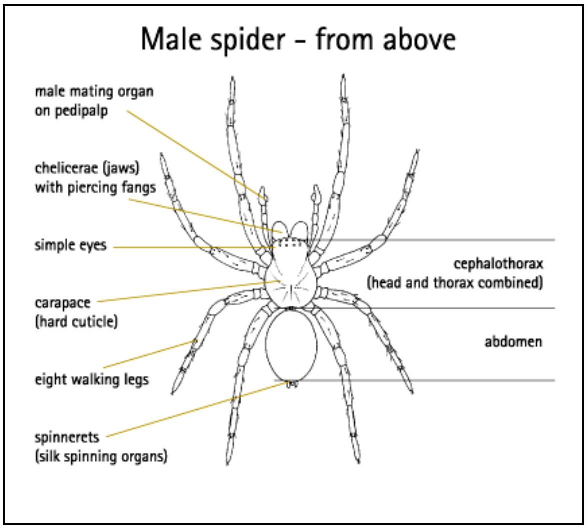


Table 33. Differences Between Insects and Spiders

INSECTS	SPIDERS
• With three (3) body divisions – head, thorax and abdomen	• 2 body divisions – cephalothorax and abdomen
• Antennae present	• Antennae absent
• Thorax and abdomen are segmented	• No division; body is not segmented
• Eyes are compound	• Eyes are simple
• Has six (6) legs	• Has eight (8) legs
• Has at least one pair of wings	• No wings
• Cerci are present at the end of the abdomen	• Cerci are missing
• There are no spinnerets	• Three of four pairs of spinnerets appear in the abdomen for production of silk threads
• Metamorphosis is usually present	• Development is direct
• Belongs to Insect / Arthropoda / Hexapoda family	• 10. Belongs to the Arachnida family

The Arachnida

Many people consider spiders as far less worthy of admiration than their webs, but in fact, spiders are marvelous creatures. Some people think spiders are insects, but this is not so. They are related to insects in that both are **arthropods**, having jointed legs and external skeletons, but much of the similarity ends there. Spiders have two body parts (**cephalothorax** and abdomen), and insects have three (head, **thorax**, and abdomen). Spiders have eight legs, but insects have only six. Most insects possess both **antennae** and **wings**, whereas spiders lack both. Spiders have **pedipalps** or appendages located between the jaws and the front legs, but insects do not. These pedipalps are sense organs that also function as sex organs in males.

Spiders belong to the class **Arachnida**, as do scorpions, mites, and daddy longlegs (harvestmen). The scientific name is derived from the Greek word for spider, arachne, which comes from the name of a legendary Greek maiden who challenged the Goddess Athena’s spinning ability and was turned into a spider for her audacity. Spiders and their relatives are called arachnids. Arachnids have the head and thorax combined (cephalothorax) with simple eyes, jaws adapted for tearing or piercing prey, a pair of pedipalps and eight walking legs. Arachnids include spiders, scorpions, pseudoscorpions, whipspiders, harvestmen, ticks and mites.

The English word spider can also be traced from the word “spinder,” one who spins. Almost all spiders can spin silk and are able to do so from birth. The spinning organs are fingerlike projections called **spinnerets** that can be extended, withdrawn, compressed, and to some extent, aimed. They are located near the end of the abdomen on the undersurface. These spinnerets are tipped with many **spigots** from which the silk is released. The silk is produced from glands within the abdomen; as the fluid leaves the spider’s body, it hardens quickly to form the familiar silken thread. Scientists have identified at least seven different kinds of spider silk, each used for a specific purpose.

Spider silk has considerable strength and elasticity. A one inch thick rope of spider’s silk would be stronger than a one-inch steel cable. Some of the threads will stretch nearly one-half their length before they break. The thinnest lines are only one-millionth of an inch wide, and thus invisible to humans, but other lines are much heavier.

Not all spiders spin webs, but those that do, use them to catch insects. When an insect is caught in a web, the spider (often hiding off to the side) feels its attempts to struggle free and escape. A spider can determine from the pattern and strength of the vibration whether **prey** has been caught, a mate is signaling his arrival, or a **predator** is approaching. Generally, if an insect is caught, the spider rushes towards the prey and injects it with venom or throws a strand of silk over it to disable it. Many spiders wrap their prey in silk to trap and store them before eventually ingesting them. Spiders have small mouths and cannot eat solid food. They must either inject digestive fluids into the insect’s body or secrete these fluids over it to dissolve the tissues that they then suck in. If an unpalatable insect is caught, the spider will cut the threads around it until the insect drops out of the web.

Growth and Longevity

Spiders grow by periodically shedding their semi-rigid external 'skin' or cuticle of semi-rigid chitin and replacing it with a new larger skin they have grown underneath the old one. This process is called ecdysis or moulting. This process includes replacement of every hair on the body and internal cuticular structures such as the fore and hind gut linings and female genitalia. Once they are mature most araneomorph spiders stop moulting. However, female mygalomorph spiders moult throughout life, although at longer intervals as they get older. This allows some species, particularly tarantulas (Theraphosidae), to grow very large.

During the moulting process, which may take many hours, the spider is in great danger from predators, being soft-bodied and unable to move until its new cuticle has hardened. For this reason moulting is often done at night when the spiders hung safely in mid-air from a silk line; or sealed within a silk retreat or moulting chamber, e.g., in a curled leaf, a burrow, or under bark.

Egg Sac to Adult

Spider eggs develop and hatch within the egg sac; the larval spiders undergo at least one further moult before emerging from the sac. The number of growth moults varies between species, as well as with size and nutritional state. Poorly fed spiders will moult fewer times and become smaller adults. Most spiders undergo 5-10 moults to reach adulthood. Males often have fewer and faster moults. Extreme examples of this are given by the Magnificent spider (Ordgarius magnificus) and the Bird Dung spider (Calaenia kinbergi), both large, specialised moth-catching relatives of the orb weavers. The males moult only within the egg sac, emerging as tiny, fully mature males along with their similarly sized and very immature sisters, which will take many weeks and moults to become large adult females.

A spider's appearance can change considerably during growth from spiderling to adult, as indicated by these stages in Redback spider development. Adult males and females also may look quite different, especially in respect of size and colour. Spiders with good eyesight like jumping spiders often have colourful or strikingly marked males which differ considerably from their less colorful females.

What Spiders Eat?

Spiders eat invertebrates (insects and other small animals without backbones) and larger spiders may eat small vertebrates such as frogs and some birds. Spiders in Australia have developed many different ways of finding and catching food. Some hunt for prey at night while others hunt during the day. Some prowl around and pounce on their prey while others wait for prey to come to them. Most spiders inject their prey with venom from their fangs. This venom helps dissolve the tissues of the prey's body so the spider can suck it up as a liquid.

INTEGRATED PEST MANAGEMENT (IPM): CONCEPTS, PRINCIPLES, AND RESEARCH

Integrated Pest Management (IPM) began in the mid 1950's as "Integrated Control" which is the integration of biological and chemical controls into a cohesive pest management system. Years later, several aspects were added to the original concept resulting to what is now called IPM philosophy. IPM is the **selection, integration,** and **implementation** of pest control that is ecologically sound, economically viable and socially acceptable.

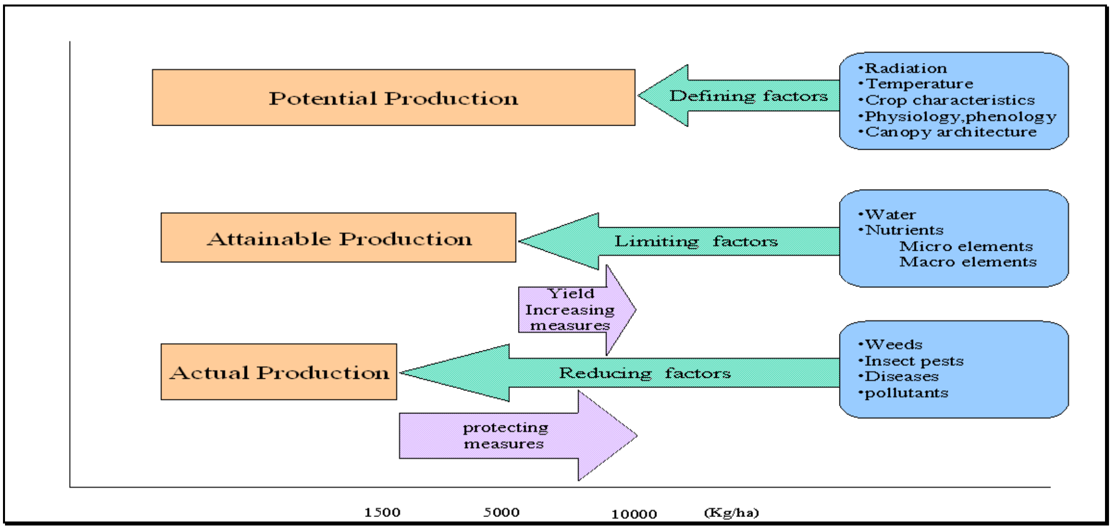
There are several principles involved in IPM. One is that ***a species is not a pest unless it exceeds tolerable level***. In the field, most plant feeders and natural enemies live in a system where population levels are tolerable; rarely reaching an outbreak proportion. However, resurgence in population due to application of broad spectrum insecticide occurs as in the case of the brown plant hopper (BPH) in rice.

Another principle is that ***the ecosystem is the management unit***. Any intervention or manipulation will affect not only one species but the whole community of organisms that live in it. A very important principle is that natural control should be maximized. Natural control is the suppression of a population by forces of the environment that includes physical and biological factors (predators, parasitoids, and pathogens). There are rich communities of natural enemies that can be found inside the crop ecosystem.

The overall objective of IPM research is to reduce yield losses due to pests. In attaining this objective, research should focus on important concerns: (a) Profit; (b) Health and safety; (c) Environment; and, (d) Ecological stability and sustainability.

It is important to plan research activities according to the different concerns. IPM also deals about socio-economics. If a technology is uneconomical or unacceptable to the farmers, then the implementation is difficult.

Production Situation



Production level

Schematic overview of production situations with corresponding yield levels and factors that influence crop growth (Lovenstein, 1992)

Principles of Primary Production

In the analysis of primary (and also secondary) production systems, the production level is influenced by three categories of growth factors:

1. ***Growth-defining factors*** determine the potential yield, which is realized when crops grow with an ample supply of water, nutrients and other resources in the absence of weeds, pests, diseases or other injurious factors. Growth defining factors include site-specific environment variables, such as temperature and incident radiation, which depend on latitude and day of the year, and species-specific characteristics concerning physiology and geometry of the leaves and roots, and phenology. **Phenology** refers to the time of development, which depends on the environmental factors such as temperature and daylength. Situations where potential growth rates are reached are rare, and may occur only in protected cultivation.

2. ***Growth-limiting factors*** comprise abiotic resources essential to crop growth such as water and nutrients, which limit the growth rate of the crop to a value below the maximum when their supply is sub-optimal. The associated yield level is called **attainable production**.

3. ***Growth-reducing factors*** either hinder crop growth or affect the crop itself. Due to these factors crop production is reduced from the attainable yield level to the actual yield level, referred to as **actual production.** Growth-reducing factors include both biotic (weeds, pests, and diseases) and abiotic (pollutants of air, water, and soil and extreme weather conditions) factors.

Table 9. Strategies, Tactics, and the Relative Sequence of Tactical Implementation Necessary to Develop and Implement a Successful IPM Program

Prevent or Avoid Pests and their Damage ➢ Maintain vigorous, healthy plants by using proper culture and management practices. ➢ Practice IPPM and realize that all culture and management factors can affect pests. ➢ Use plant host resistance; select and grow cultivars or species that have fewer pests. ➢ Scout plants for pests, use phenology records and thresholds to make spray decisions. ➢ Use soaps, oils and biologicals (least toxic chemicals) whenever possible. ➢ Spot spray only infected plants that exceed the threshold. ➢ Destroy heavily infested or injured plants. ➢ Match beneficial species to pest and plant.
Use Host Plant Resistance ➢ Determine the pest profile of target species and cultivars in the target habitat. ➢ Grow and evaluate the germplasm under the range of conditions to which it will be exposed. ➢ Select species or cultivars with lowest numbers of pest. ➢ Determine the effects of culture and management practices interacting with the environment on pest occurrence (plant x environment interactions). ➢ Determine the impact of different cultivars on beneficials. ➢ Grow the less susceptible stock and monitor it for efficacy of tolerance/resistance.

Use Biological Control Agents or Beneficials (Conservation and Augmentation) ➢ Reduce overall pesticide use especially the toxic pesticides by practicing IPPM. ➢ Sample pest populations and use economic/aesthetic thresholds. ➢ Keep accurate records of pest's seasonal abundance. ➢ Know pest profile of plants because multiple pests may present problem. ➢ Tolerate low level pest populations to sustain beneficials. ➢ Use soaps, oil and biological as prevention to conserve natural beneficials. ➢ Use selective pesticides that are easy on beneficials. ➢ Match beneficial species to pest and plant. ➢ Release beneficials when pest populations are expected (records) or first detected. ➢ Evaluate results as with other controls.
Managing pesticide Resistance ➢ Reduce pesticide use by practicing IPPM and prevent pest outbreaks. ➢ Use soaps, oils and biological as much as possible to avoid resistance pressure. ➢ Spot treat that is, apply pesticides only to infected plants so as to maintain susceptible pest populations. ➢ Rotate chemicals by class either in sequential applications or by pest generations. ➢ Manage pesticide use rate, use the lowest dose that provides control.

Integrated Pest Management Strategies

I. Biological Control of Insect Pest

Biological control defined

Biological control may be defined as the action of predators, parasitoids, pathogens, antagonists, or competitor populations to suppress a pest population, making it less abundant and less damaging than it would otherwise be. In other words, biological control is a population-leveling process in which the population of one species decreases the numbers of another species by mechanisms such as predation, parasitism, pathogenicity or competition. Biological control has proven relatively successful and safe. It can be an economical and environmentally benign solution to severe pest problems.

Biological Control Agents

Predators

A predator is an animal that depends on predation for its food. In other words, predators sustain life by killing and consuming animals of other species.

Characteristics of a Predator

- A predator generally feeds on many different species of prey, thus being a generalist or polyphagous in nature.
- A single predator kills and eats large numbers of prey in its lifetime.
- Predators kill and consume their prey quickly, usually via extra oral digestion.

- Usually, immatures and adults of both sexes attack prey.
- Predators are very efficient in hunting their prey.
- Predators develop separately from their prey but may live in the same habitat or adjacent habitats.

Parasites

A parasite is an organism living in or on another living organism, obtaining from it part or all of its organic nutrients, resulting in death for the host or altered growth, development and reproduction.

Approximately 10% of all insect species can be classified as parasitoids. The main difference between parasites and parasitoids is that parasites may not kill their hosts but parasitoids do. Parasitoids play a key role in the biological control of insect pests. About 75% of the parasitoids are Hymenoptera, the remaining 25% is composed of Diptera and some Strepsiptera, Neuroptera, Coleoptera and Lepidoptera.

Characteristics of Parasitoids

- Specific parasitoid species usually attack specific insect species (specialist or monophagous) or a few closely related species (oligophagous).
- Parasitoids are host stage specific - some parasitize eggs while others parasitize larvae/pupae.
- Only the female parasitoid is involved in the act of parasitism. Many of them have a highly developed long ovipositor to lay eggs in their host body and in some cases they attack hosts that are inside plant tissue.
- Only the larval stage of the parasitoid is parasitic; adults are free living and feed on nectar, honeydew or host insect body fluid.
- Female parasitoids lay a single egg or several eggs in, on, or near the host body. Newly emerged parasitoid larvae feed inside the host body, and gradually destroy the host as it develops.
- Pupation of parasitoids can take place either inside or outside the host body.
- A parasitoid completes its development on one host individual.

Parasitism Terminology

Different parasitoids may attack the various growth stages of a pest. Thus, there may be egg, larval, pupal, nymphal and adult parasitoids. Parasitoid species may be solitary (only a single parasitoid can develop on a single host) or gregarious (several parasitoids of a single species can develop on a single host).

In some species, adults deposit a single egg per host, which subsequently divides into many cells, each of which develops independently. This process is called polyembryony. If more eggs are deposited by a single species in a host than can survive, the result is termed superparasitism. If two or more species of parasitoids attack the same host, the resultant condition is described as multiparasitism.

Parasitoids that insert their eggs into hosts are called endoparasitoids; those that lay their eggs externally and whose larvae develop externally are called ectoparasitoids. Parasitoids of non-parasitoid hosts are primary parasitoids. Parasitoids that attack other species of parasitoids are hyperparasitoids.

Parasitoids of Insect Pests

Parasitoids are a very important component of the natural enemy complex of insect pests and have been the most common type of natural enemy introduced for biological control of insects. Members of 43 families of the order Hymenoptera are parasitoids. Twelve families of Diptera contain some species whose larvae are parasitoids of arthropods and snails. Of these, only the Tachinidae have been of major significance in biological control as introduced natural enemies.

So far, parasitoids of 26 families have been used in biological control. The most frequently used groups in the Hymenoptera are Braconidae, Ichneumonidae, Eulophidae, Pteromalidae, Encrytidae and Aphelinidae. Some parasitoids are also found in the insect order Strepsiptera, Lepidoptera and Coleoptera, although parasitism is not typical of the Lepidoptera and Coleoptera.

Pathogens

Pathogens Attacking Arthropods

More than 1500 species of pathogens are known to attack arthropods. These include bacteria, viruses, fungi, protozoa and nematodes. Some pathogens have been formulated as micro-biological insecticides. Others have been genetically engineered but none have been commercialized.

Bacteria

Among the various pathogen groups, bacteria have been the group most successfully brought into commercial use. Three species of spore-forming bacteria in the genus Bacillus are currently used for the control of several groups of pests, the most widely used of which is Bacillus thuringiensis (Bt.). About 30 subspecies of Bacillus thuringiensis and more than 700 strains have been identified. Bt. products are available for control of lepidoptera, coleoptera and diptera.

Viruses

At least 16 families of viruses have been found to be pathogens of insects. Members of Baculoviridae frequently cause lethal infections and are only known to cause disease in insects. Few viruses have been marketed as commercial products because their production costs are high and they have narrow host specificity.

Fungi

More than 400 species of entomopathogenic fungi have been recognized. These fungi are found under five subdivisions: Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina. Fungal epidemics occur periodically and can cause high levels of mortality in affected arthropod populations. Successful development of fungal pesticides has been limited because of narrow host range, and high humidity requirements for germination or sporulation, but have great potential for use in humid climates or moist environments such as soil.

Protozoa

Protozoa infecting insects include micro-sporidians and the eugergarines. Some have been considered for use as microbial insecticides. Species of Nosema are potential biocontrol agents for grasshoppers.

Nematodes

Nematodes that have shown potential for the control of agricultural pests are members of the families Steinernematidae and Heterorhabditidae, which are mutualistically associated with bacteria that kill the nematode's host. Nematodes in some other families also kill their host insect through their growth, as do parasitoids. These include mermithidae, phaenopsitylenchidae, iotonchiidae, sphaerulariidae and tetradonematidae.

Biological Control Approaches

Large numbers of biological control agents are active in the field and are naturally performing biological control functions. This phenomenon is known as naturally occurring biological control or natural biological control. Natural biological control is the most important component of pest management in crop fields. In its absence, crop production would be extremely difficult.

Natural biological control is often limited by factors such as low plant diversity and its consequences for natural enemy populations - pesticide use or highly seasonal planting of field crops. As pests enter crops early in the season, and start to grow rapidly on abundant food, it is difficult for natural enemies to keep up with them.

Therefore, in order to create favorable situations for natural enemies, interventions are often necessary. There are three major interventions:

1. conservation
2. augmentation and
3. introduction or classical biological control

II. Cultural Control of Insect Pests

<u>Definition of Cultural Control</u>

Cultural control is the modification of production practices to make the environment less favorable for pest invasion, reproduction, survival and dispersal. Its aim is to achieve reductions in pest numbers.

Most of the traditional agronomic practices have a dual purpose of crop production and pest suppression. Rice establishment through transplanting of seedlings is a good example, which effectively suppresses weeds and reduces the incidence of seedling pests. Farmers have developed these practices through observation and trial and error. These crop production practices are transferred from generation to generation, usually consisting of farm-based technology with little dependence on outside resources.

Modification of any crop production practice ultimately affects yield through complex interactions with the crop and environment. All crop production practices affect insect pest populations either positively or negatively. A single practice such as plant spacing or time of planting may produce opposite effects on different pest species. Often they counterbalance one another. The use of low fertilizer rates or draining the fields is highly effective in suppressing certain insect pests, but may result is lower yield.

The development of cultural control methods requires a thorough knowledge of the life history and habitats of the insect and its plant host. Farmers must decide which cultural practices are best for their location, such as direct seeding or transplanting seedlings in a wetland environment.

Advantages and Disadvantages of Cultural Control

Advantages:

- Most cultural control practices are inexpensive or use resources available to farmers, such as labor or indigenous materials.
- Adoption of pests against a cultural control practice appears to be a much slower process than that of pesticides and resistant host plants.
- Cultural control practices are generally free from environmental pollution.
- Most cultural control practices are compatible with other pest management practices.

Disadvantages:

- Most methods suppress populations of some pests but can increase some others.
- Some practices decreases pests but also decreases yield.
- Many practices require community-wide adoption, which may be difficult to achieve.

Cultural Control

Vigorous, rapidly growing plants often 'outgrow' pest damage. You should plant recommended cultivars, maintain fertile soil with proper pH and moisture providing your vegetable field means to outgrow pest damage.

Sanitation **-** dispose of infested plant and trash materials that harbor pests and cultivate the soil to expose and destroy pests in the soil.

Weed control **-** keep the garden border areas trimmed and cultivate the garden to control unwanted plants (weeds) that serve as hosts to insects that can move over to your vegetable plants.

***Time your plantings* -** many insect pests, including the corn earworm and squash bug, are less numerous early in the season and an early planting of vegetables will often 'escape' with little to no damage.

Traps are devices that collect or cause insects to congregate, such as flat boards on top of the soil in the garden. Check the traps frequently and collect and destroy the insect pests in the traps.

Barriers serve to exclude pests from the crop and include the use of paper collars around the stem collar of young transplants that prevents cutworms from attacking and destroying plants. Other barriers include row covers made of transparent or translucent covers of woven plastic that allow light to enter, but block insects. Typically, these row covers are supported above the plants with hoop frames although light weight woven covers can rest on the canopy.

Mechanical removal by hand picking or washing with a directed stream of water is effective for large insects or eggs and for small, soft-bodied insects or mites.

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PART VIII: COMMON DISEASES OF VEGETABLE CROPS AND THEIR MANAGEMENT

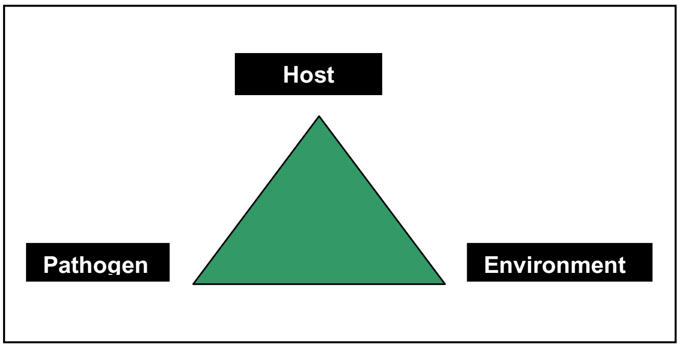
What is a Disease?

- An abnormal condition that injures the plant or causes it to function improperly (Reissig, W.H. et al, 1986).
- Any disturbance that interferes with the normal structure (e.g., height, tillers, leaves), function (e.g. reduced vigor, early death), and economic value (e.g. reduced yield, poor quality produce) of the plant (HOST) is a disease (Philrice, 2002)

A plant disease can be identified or diagnosed through the characteristic or characteristics manifested by manifestation of diseased condition (symptoms) and the presence of visible structures (signs) produced by the pathogen.

The causal agent (PATHOGEN) may be either a living (BIOTIC) or nonliving (ABIOTIC) agent. Biotic agents have the ability to enter and colonize plant parts and other plants (INFECTIOUS). When disease increases rapidly in a large plant population over time, a serious outbreak occurs (EPIDEMIC).

A. Disease Triangle



A disease is the result of the interactions between a pathogen and a host in a pathogen and a host in a favorable environment. A disease generally occurs because the host is susceptible, the pathogen (causal agent) is virulent, and the environment is conducive for the disease to grow.

Examples of environmental factors for disease to occur are:

1. *Temperature* – Bacteria grow rapidly at high temperature. Most insects are also active and multiply fast in warm temperature.
2. *Moisture* – High moisture content enhances high germination rate of fungal spores, affects bacteria in entering into plant tissue cells, and increases number
3. *Wind* – wind disperses fungal spores over distance. Strong wind damages plant tissues, thus, creating entry points for bacteria. Light wind current is favorable for insects' movement.

B. Common Causes of Plant Disease

A. Nonliving (abiotic) factors

- Not spread from diseased to healthy plants
- Can be recognized only through their symptoms

  e.g. Drying of leaves – lack of moisture or chemical burn
  Yellowing of leaves – nutrient deficiency

- Can be avoided by providing the factor that is lacking
- More often affects a large area within a brief period

B. Living (biotic) factors

- Are caused by organisms that spread from diseased to healthy plants
- The organisms are very small
- Can be recognized by symptoms and signs
- Can be managed by destroying or removing the parasitic agent and reducing the number of pathogen and infection rate

C. What are Symptoms, Signs and Syndromes of Common Plant Diseases?

A *symptom* is the physical expression of a change in the appearance and function of the plant. Examples of symptoms are:

• Blights	• Rots
• Cankers	• Necrosis
• Galls	• Spots

A *sign* is the visible presence of the pathogen, such as a fruiting body or discharge associated with the disease. Examples include the following:

- Conks
- Mycelia
- Ooze (flux)
- Pycnidia
- Rhizomorphs

A disease *syndrome* is the group of signs and symptoms which collectively characterize a disease. Familiarity with the signs or symptoms of the disease is not enough to diagnose a disease; it is necessary to know the syndrome and case history. Seeing a spot on a leaf does not tell much, but finding pycnidia in that spot and knowing the plant species and recent weather conditions might be sufficient information to diagnose the disease. Other cases, laboratory work is necessary for diagnosis.

Signs and Symptoms of Common Plant Diseases

1. **Alteration of Normal Appearance -** Examples include mosaic patterns of light and dark green on leaves, and altered coloration in leaves and flowers.

2. **Bacterial Leaf Spots -** Pots are often angular due to limitation by leaf veins. Color is usually uniform and no signs of plant pathogen are evident. Tissue may initially appear water-soaked but may become papery as it dries.

3. **Blights -** Symptoms include sudden withering and death of leaves and branches, or in the case of blossoms, wilting and discoloration. Conspicuous spots or irregular dead areas on leaves and twigs which cause foliage to distort and drop prematurely, could be blight. Damage from blights can range from minor, as in the case of some anthracnose blights to serious, as in the case of fireblight.

4. **Chemical Spray or Air Pollutant Injury** - Spots associated with injury are relatively uniform in color and the interface between the affected and healthy areas is usually sharp. Distribution on plants may be associated with the areas where spray or pollutant comes in contact with the plant.

5. **Chlorosis** – This is a yellowing of leaf tissue due to a lack of chlorophyll. Possible causes of chlorosis include poor drainage, damaged roots, compacted roots, high alkalinity, and nutrient deficiencies in the plant. Nutrient deficiencies may occur because there is an insufficient amount in the soil or because the nutrients are unavailable due to a high pH (alkaline soil). It is also possible that the nutrients are not absorbed properly because of injured roots or poor root growth.

6. **Damping-off -** This term describes the rapid death and collapse of young seedlings. Often the seedlings appear to be almost broken at the soil line. It may be observed in flats of plants begun in greenhouses and can result from infection of the seedlings by the fungal organisms *Fusarium, Phytophthora, Pythium, Rhizoctonia*, or *Thielaviopsis*.

7. **Fruit Decays and Rots** - Various fungi and bacteria can cause fruit rots. These are often distinguished by the color, lack of firmness of tissue, and signs of spores or fruiting bodies.

8. **Fruit Discoloration** - Discoloration of fruit is often associated with viral infections. This discoloration may be similar to mosaic and ringspot symptoms observed on leaves.

9. **Fungal Leaf Spots** - Spots usually vary in size. They are generally round and occasionally elongated on stems. Zones of different color or texture may develop giving the spot a "bull's eye" effect. Spots are not limited by leaf veins.

10. **Galls** – These are swollen masses of abnormal tissues that range in size from small to quite large. Certain insects can also cause galls. Cut a gall open and

search for signs of an insect inside. If there is none, the gall is probably caused by a disease.

11. **Leaf Blisters** – These are yellow bumps on the upper surfaces of the leaves with gray depressions on the lower surfaces.

12. **Leaf Curl Diseases** – This causes new leaves to be pale or reddish with the midrib deformed. The leaves pucker and curl as they expand. Certain insects cause similar symptoms. So on closer inspection, if the insects themselves are the cause, the insects or other signs of their presence can be seen.

13. **Leaf Distortion** - Leaves of the infected plant may be distorted from their normal shape and size. Leaves may be elongated, smaller in size, or thickened. This type of symptom can be associated with viral, fungal or bacterial infections as well as insect and mite infestations.

14. **Mildews** – Mildews are usually one of two types. Downy mildew is usually a white to purple, fuzzy growth, usually on the undersides of leaves and along stems. It turns black with age. Powdery mildew is a white to grayish powdery growth on the upper surfaces of leaves.

15. **Mosaic and Ring Spots** - Mosaic and ring spots are used to describe an irregular patchwork of green and yellow areas over the surface of a leaf. In some cases leaves may also become distorted. Often these symptoms are associated with viral pathogens. There is not a sharp margin between the affected and healthy areas. Distinct margins may indicate a nutritional problem or genetic variegation.

16. **Necrosis or Death of Plant Parts -** These may be some of the most noticeable symptoms, especially when they affect the entire plant. Examples are wilts or diebacks. Other examples include shoot or leaf blights, leaf spots, and fruit rots.

17. **Overall Stunting and Decline** - These symptoms can be caused by several and very different factors. Systemic viral infections can result in stunting or decline, but such viral infections are often accompanied by other aboveground symptoms like shortened internodes. In many cases, overall stunting of a plant may be due to problems associated with the root system. The roots should be examined for rotting and possible mycelial growth, reduction in roots especially feeder roots, and the presence of galls. Root galls can result from fungal and fungal-like agents (*Plasmodiophora brassicae)*, nematodes (*Meloidogyne* spp. - root-knot), and bacteria (*Agrobacterium* sp.). Abiotic factors such as nutritional deficiencies, soil compaction and herbicide residues can also result in overall stunting or decline.

18. **Overdevelopment of Tissues and Organs -** Examples include galls on roots, stems, or leaves, witches' brooms, and profuse flowering.

19. **Powdery Mildew** – Powdery Mildew can affect leaves, stems, flowers and fruits with a white to gray surface coating of mycelia which can be rubbed off. Black specks may later develop in the mycelia. These specks are mature cleistothecia, the overwintering fungal structures which contain ascospores. Tissue may turn

yellow, reddish or remain green under the mycelia and some leaf distortion may be observed especially on actively growing tissues.

20. **Rot Diseases** – These cause decay of roots, stems, wood, flowers, and fruit. They can be soft and squishy or hard and dry, and color can be either light or dark.

21. **Rust Diseases** – Rust diseases typically produce symptoms that include a powdery tan to rust-colored coating or soft tentacles.

22. **Soil or Air Chemical Injury** - Chemicals which are absorbed from the soil by roots or absorbed from air through leaves may exhibit a burning or scorching of leaf margins. If severe, islands of tissue between the veins may also be killed. Dead tissue may drop out of the leaf leaving a ragged appearance. Other chemicals may cause a distortion of leaf shape and size.

23. **Wilt Diseases-** These cause permanent wilting, often followed by death of part or all of the plant.

24. **Underdevelopment of Tissues and Organs -** Examples include such symptoms as stunting of plants, shortened internodes, inadequate development of roots, malformation of leaves, inadequate production of chlorophyll and other pigments, and failure of fruits and flowers to develop.

Table 34. Common Diseases of Vegetables

Problem	***Hosts***	***Symptoms and Sign***	***Management***
Damping off *Phytium sp.* *Fusarium sp.* *Rhizoctonia sp.* *Phytopthora sp*	Crucifers Solanaceous Legumes Cucurbits	• Damping-off is essentially a seedling disease. Infected plant shows soft-girdled, rotted stem near the soil line causing young seedlings to topple down. Symptoms are brown, water-soaked areas around the lesion that shrivel and pinch the seedling off at the base. • The dry rot is usually limited to the outer part of the stem and infected plant may fall down or may remain more or less upright. Infected plants remain under developed and usually die.	• The fungi that cause these seedling diseases are soil inhabitants. To reduce plant losses, sterilization of soil for growing seedlings; use of healthy seeds dressed with fungicide; nursery beds located on well-drained sites; and well ventilated beds are helpful.
Bacterial wilt *Ralstonia solanacearum* *Pseudomonas solanacearum*	Solanaceous	• Sudden wilting of leaves and death of the entire plant unaccompanied by any yellowing or spotting of leaves. • Brownish discoloration appears in vascular tissues of the basal part of the stem. Also, roots are formed on the stem. If the stem is cut, milky white exudes ooze out from	• Since the bacterium is soil-borne, soil treatment is effective in controlling this disease. Hot water treatment of seeds at 50oC for 25 minutes effectively reduces the bacteria that stick to seeds. • Rotation of non-solanaceous crops; growing of seedlings in bacterial wilt-free beds; and planting of tomatoes away from

		the vascular system after suspended in water. In later stage of the disease, decay of the pith cause extensive hollowing of the stem.	the land previously infected with bacterium to prevent infection from drainage water are important in the management of bacterial wilt disease. • Use of compost may reduce bacterial wilt. High organic matter in the soil improves conditions for microorganisms including antagonistic organisms that may work against Ralstonia bacteria.
Downy mildew *Pseudoperonos pora cubensis (Berk and Curt) Rostow*	Solanaceous Cucurbits	• The disease appears as yellow spots on the surface of the leaves with a purplish downy growth on the lower surface. These yellow spots may soon turn reddish-brown and eventually kill the leaves. When infected plants do not die, the fruits may not mature, and the flavor is poor.	• Major control measures include the use of resistant varieties and crop rotation. Wider spacing between plants and planting sites with good drainage and ventilation also helps check disease development by promoting good aeration and rapid drying of plant surfaces. • Use of clean seeds or hot water treatment will lessen the disease development. Practice sanitation and destruction of plant debris will likewise help to eliminate the disease. When seedlings show symptoms of downy mildew, try applying some extra nitrogen. Seedlings tend to outgrow the disease if they are top-dressed with nitrogenous fertilizer.
Fusarium wilt *Fusarium oxysporum*	Solanaceous	• The fungi may infect the plant at any age. Initial symptoms are yellowing of the leaves near the base of the plant followed by wilting. One or more branches may be affected while others remain symptomless. • As the disease progresses, yellowing develops on the upper leaves. Affected leaves may sometimes dry up before wilting is detected. The vascular system of the affected stem and petioles becomes brown and can be detected by cutting them diagonally.	• Seeds from healthy plants and treating the seeds with hot water will help reduce the incidence of this disease. Precautions must be taken to reduce the spread of infested soil on implements and workers during movement among greenhouses and fields. • Rotation might help limit the development of new races of this persistent soil-borne pathogen. Do not apply excessive fertilizer and use disease-resistant varieties.
Septoria Leaf Spot *Septoria lycopersici Spegazzini*	Cucurbits Legumes	• The disease affects any stage of the plant but it is more evident during fruit setting. Symptoms occur on petioles, stem and calyx. • The initial symptoms are characterized by small round water-soaked spots scattered	• The pathogen can survive in or on seed, disease plant debris, and in infected perennial weeds and plants. • Spores and other fungal structures are disseminated by water, farm tools, insects, and wind. Disease epidemics can be

		fast on older leaves and progress then on younger leaves as the disease develops. • The spots soon become roughly circular and have gray centers surrounded by darker margins. Later the centers show tiny dark specks where spores of the fungus are produced. The leaves may become dry and may later fall off the plant.	avoided by using pathogen-free seeds, crop rotation and sanitation. Cool weather slows disease development. Use of fungicides can reduce the rate of disease increase.
Powdery mildew *Leveillula taurica (Lev) Arnaud* *Oidiopsis taurica Tepper*	Legumes Parsley solanaceous	• Initial symptoms are small, white powdery spots that first appear on the upper surface of the leaflets and soon become evident on both surfaces. • Affected tissues turn yellow. In serious cases, the mildew covers the entire leaf until it shrivels and dies. The disease progresses from the older to younger leaves. The pathogen also affects stem, petioles and floral parts.	• Treat seeds with hot water before sowing. • The use of sprinkler irrigation and fungicidal spray can help in reducing the development of the disease.
Bacterial Spot *Xantomonas campestris pv. vesicatoria*	Crucifers Cucurbits	• Leaf lesions begin as water-soak, circular to irregularly-shaped spots that become necrotic with brown centers and chlorotic borders. • More numerous on young than old leaves. Lesions are slightly sunken on the upper leaf surface and slightly raised on the lower surface. Lesions sometimes coalesce and severely infected leaves turn yellow and drop. • Fruit symptoms start as water-soaked brown dots and then become raised, wart-like in appearance surrounded by a lighter halo. Narrow, elongated lesions or streaks may develop on stems.	• The bacterium can be seed-borne and persists in crop debris and weeds. Warm temperatures, sprinkle irrigation or heavy rains enhance the severity of the disease. Seed cleaning along with crop rotation, helps in the prevention of disease outbreaks, while copper compound sprays reduce the rate of disease development.
Alternaria leaf spot *Alternaria brassicae*	brassicae	• Symptoms of alternaria leaf spot usually appear on the older leaves of the cabbage plant. The spots begin as black pinpoint-sized spots and enlarge to distinct brown-black leaf spots of 1-2 cm diameter with concentric rings and sometimes yellow area around the spot. • The concentric rings contain	• To prevent the occurrence of the disease, use clean seed that is treated in hot water of 50oC for 30 minutes. This will kill spores that are attached to the seed. • Sanitation, destruction of cruciferous weeds and crop rotation also help reduce the development of the disease. When planting, orient rows in the direction of prevailing winds for

		the spores within which the fungus spreads. These have a dark and dusty appearance. Spores develop on the leaf spots during moist periods. Cool, wet weathers favor disease development. This is why leaf spot is usually not a problem during dry season, but it can be severe in the wet season.	better circulation of air through the foliage and use planting site and plant spacing pattern that expose plants to full sun throughout the day. Avoid over crowding of plants. • Avoid working in the fields while the plants are wet to reduce spread of the disease. Plowing immediately after harvest helps eliminate the sources of airborne Alternaria and encourages the rapid decomposition of crop residues.
Gray leaf spot *Stemphylium solani Weber*	Solanaceous	• This disease is limited to leaf blades. Initial symptoms include one to several minute brownish black specks that appear simultaneously on both surfaces of the leaf. • The central killed area changes from brownish black to grayish brown as the spots enlarge and these centers crack and partially drop out to give a shothole appearance. The entire leaf then turns yellow, droops, and eventually dies. Stemphylium spots are small, evenly distributed, almost circular, and show no concentric zonation in contrast to leaf spot.	• Field sanitation and rotation practices such as those recommended for control of alternaria leaf spot can be used.
Cercospora Leaf mold *Cercospora fuligena Roldan*	Cucurbits Legumes Cricifers	• First appear as brown effuse patches on the leaf undersurface. The corresponding upper surfaces turn yellow and later brown. • In advanced infection, the patches coalesce and become necrotic. Foliage of severely infected plants dries up and dies. • Symptoms may also occur on petioles and young succulent stems, but have not been reported on fruit. • The disease progresses from older to younger leaves.	• The pathogen survives in diseased plants parts where it produces spores at the beginning of the growing season. The application of fungicides and planting resistant varieties can reduce disease losses.
Early blight *Alternaria solani* *Alternaria porri*	Solanaceous	• All above ground parts of the plant can be affected with circular brown spots with dark concentric rings and yellow margins. They occur singly or in large numbers on each leaf and form first on older lower leaves. It is	• The fungus survives in soil, diseased plant debris or organic matter. The rate of infection can be reduced by crop rotation, maintaining plant vigor, crop rotation, minimizing injury to plants, limiting leaf-wetness periods and by use of broad-

		possible for the entire plants to be defoliated and killed. • Symptom on seedlings is characterized by girdling of the stem near the soil level. Affected seedlings are stunted and may wilt and die. Fruit symptoms generally occur as black or dark-brown, oval to round spots commonly formed around the base of the calyx and may exhibit a concentric ring pattern.	spectrum fungicides and resistance.
Late blight *Phytophthora infestans*	Solanaceous	• Symptoms can appear on leaves, stems, and fruits. Small, greenish black, irregularly-shaped water-soaked lesions. Under favorable condition, they enlarge rapidly, darken, and shrivel that may kill the entire leaflets but remain attached to the plant. • In moist condition, a white downy growth of the fungus appears at the edge of lesions on the undersides of the leaves. This also appears as grayish-green, water-soaked lesion that enlarges until it covers the fruit surface.	• Good cultural practices, such as removal of crop debris, destruction of volunteer plants, not planting near potato crops and not using seedlings grown in greenhouses where lateblight has been present will help reduce disease levels. Proper disposal of collected infected plant parts also helps. • Spray fungicides while the plants are still young if the weather favorable for lateblight development is present. Use resistant cultivars.
Stem rot (Southern blight) *Sclerotium rolfsii*	Solanaceous	• Plant exhibits yellowing or wilting of the foliage beginning on the lower leaves. Dark brown lesion appears at the base of the stem. At the advance stage, a white threadlike mycelial growth covers the stem lesion. This extends upward depending on the amount of moisture present and moves downward destroying the root system of the plant. The white mycelium also grows over the soil to attack adjacent plants. Numerous globular light-to-dark brown sclerotial bodies about the size of a mustard seed are produced. Fruit or branches may become infected at the point of soil contact.	• Sclerotia are its principal means of long-term survival in the absence of a host or suitable substrate. • Deep plowing to bury sclerotia along with the removal of plant debris and crop rotation reduces disease incidence. • Eradicating weeds, avoiding dense planting, and choosing fields with soil that is not acidic, high humus and well-drained soil are helpful control measures.
Sclerotinia stem rot *Sclerotinia sclerotium*	Beans, carrots, pea, solanaceous	• The disease can be recognized by a soft, watery rot with white moldy growth stems, petioles, and leaves of plants. Infection may start on	• Rotation with non-susceptible crops (beets, onion, spinach, peanuts, corn) to lower disease incidence. Deep plowing will burry

		leaves in contact with the soil and gradually may grow through the petiole to the stem and eventually girdle it. If conditions remain moist, a large amount of cottony, moldy growth can be seen on the dead tissue. As this growth progresses, hard black, irregularly-shaped bodies called sclerotia form on the surface or in the pith of the stem	
Club root *Pseudomonas solanacearum Erw. F. Smith*	Crucifers	• The fungus causes swelling of the roots with characteristic club-like shapes and a reduction of fine lateral roots. These later reduce the root's ability to absorb water resulting to stunted growth and death of the plants under dry climatic conditions.	• Use of resistant varieties. Select clubroot-free nursery soil that is well-drained. Do not transplant seedlings that have little clubs or swollen roots that do not look normal. • Remove weeds that can be a host of clubroot and other diseases. • Uproot infected plants including all the roots and destroy them. Apply lime to raise the pH level to around 7. Sterilize the soil to kill the spores of the fungus. Applying fungicides is not effective to control the fungus because the spores are very strong and may still be inside the plant roots.
Tomato Mosaic Tobacco mosaic virus (TMV) Tomato mosaic Virus (ToMV) Cucumber mosaic Virus (CMV) Potato Virus Y (PVY)	Eggplant Beet, pepper, tomato, potato, spinach, turnip, tobacco	• TMV causes plant stunting, leaf stunting, mottling, deformation and occasionally drying. Leaf symptoms include mottling with raised dark green areas and some distortion on young to youngest leaves. Leaf symptoms first appear on crown leaves, which turn downward, become rough, crinkled and may curl downward at the margins. Sometimes, green fruits are mottled. Affected plants may be stunted. • ToMV – creates green mosaic and fern-leaf symptoms. Stunting of plants when attacked at early age. Some varieties exhibit severe defoliation. • CMV causes severe stunting. The leaves are moderately or severely malformed and the internodes become short. Some varieties have narrow leaves and malformed fruits	• Viruses are very persistent and infectious, and can be spread by merely brushing against plants. Infected seeds and crop debris often serve as primary sources of inoculum. These viruses can be eliminated from seed coats by soaking seeds in 12.5% solution of trisodium phosphate for 30 minutes. • During cultivation, disinfect hand or tools after working in an infected plot. Rogue out infected plants. Bury tomato debris in the soil as this disease can be transmitted by root contact.

		having yellow blotches. • PVY creates green mottling and dark vein banding. Sometimes, fruits are malformed.	
Tomato yellow Leaf Curl Virus *Transmitted by whitefly (Bemisia tabaci)*	Tomato	• Yellowing and curling of the leaves and stunting. Some varieties show severe cupping and curling of leaves while some exhibit rosette type of symptoms. • Flowers are often aborted and wilted. Plants may be excessively branched and those that survive set very little fruits.	• Control insect vector by using systemic insecticides like dimethoate, fenitrothion, and fenthion. • Remove weeds; use barrier crops like maize two months before transplanting seedlings; avoid planting solanaceous and malvaceous plants near tomatoes, rouging; and use of resistant varieties.
Root knot *Meloidogyne incognita* *M. hapla* *M. javanica* *M. arenaria* *M. graminicola*	Solanaceous Legumes Parsley	• Affected plants exhibit stunting and yellowing of the leaves. During hot weather, affected plants wilt. Root galls or knots of varying sizes and shapes are present on the roots. Galls on small roots may be as small as 1 or 2 mm in diameter while it may appear larger on roots.	• Egg masses of the nematodes are enclosed by viscous coating that protects the eggs for more than 2 years. They are disseminated via contaminated plants, tools and irrigation water and commonly found in light sandy soils. • Since root-knot nematode deposit their eggs in an external egg mass that is unprotected, nematode population can be reduced through the use of soil fumigants and nematicides. • The wide host range of Meloidogyne sp. has made crop rotation scheme difficult. Removal and destruction of the root system of the affected plants which contain high population of nematodes; deep plowing during summer to expose the nematodes to sun; and use of resistant plants are helpful in managing root-knot nematode disease.
Namamarako (maleness) *NMK virus transmitted by Aphis gossypi and Myzus persicae*	Cucurbits	• Typical symptoms include wrinkling of leaves followed by thickening of leaves, which become shiny or 'plastic' in appearance. Later older leaves most often have yellow patches and the number of female flowers is severely reduced. In severe infection, plants could be stunted and sometimes, even male flowers are hardly produced	• Sanitation or removing of weeds that serve as alternate host of the vector of the virus disease is one of the preventive measures for this disease. • Control of the insect vector is necessary to limit the transfer of the disease. Proper fertilizer management is also necessary to produce vigorous plants.
Phomopsis Fruit Rot	Eggplant	• Phomopsis is a fungal disease that is soil-borne. It spreads with water splashing from soil to plants or from plant to plant with irrigation and rain.	• The most effective method or control is to collect infected fruits and bury them. Keep field clean from rotting fruits, dead leaves and branches, and weeds.

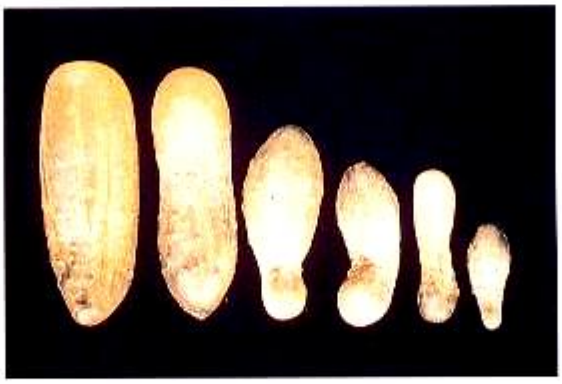
		• The affected areas on fruits are dark brown. They grow rapidly and are circular in pattern. The infected fruits turn brown and rot in a few days.	Keep fruits from touching the soil. Provide proper aeration in the area.

CUCURBITS

1. **Bacterial wilt of melon - wilting plant**

2. **Bacterial wilt of cucumber - stringing of bacterial slime from the vascular system**

3. **Angular leaf spot of cucumber - leaf symptoms**



4. **Angular leaf spot of cucumber - fruit symptoms**

5. **Downy mildew of melon - leaf symptoms**

6. **Downy mildew of butternut squash - leaf symptoms**

7. **Downy mildew of luffa - leaf symptoms**

8. **Anthracnose of cucumber - leaf symptoms**

9. **Anthracnose of melon - fruit, leaf, and stem symptoms**

10. **Powdery mildew of summer squash - early signs and symptoms**

11. **Powdery mildew of summer squash - late signs and symptoms**

12. **Alternaria leaf spot of melon - leaf symptoms**

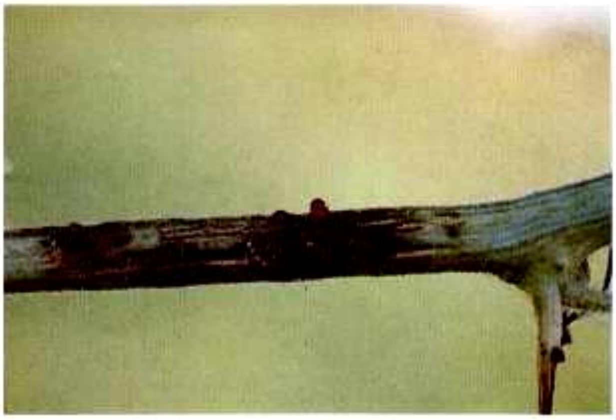
13. Alternaria leaf spot of melon - leaf symptoms

14. Alternaria leaf spot of watermelon - leaf symptoms

15. Corynespora blight of cucumber - leaf symptoms

16. Corynespora blight of cucumber
- initial leaf symptoms, water-soaked lesions

17. Gummy stem blight of watermelon - leaf symptoms



18. Gummy stem blight of watermelon - stem symptoms with gummy exudate

19. Gummy stem blight of melon - leaf symptoms

20. Gummy stem blight of melon - stem symptoms

21. Fusarium wilt of cucumber - yellowing and wilting plants

22. Fusarium wilt of watermelon - wilting plant

23. Fusarium wilt of watermelon - vascular discoloration in the main stem

24. Choanephora fruit rot of summer squash - fungal sporulation on a rotted fruit

25. Cottony leak of cucumber - decaying fruit and fungal mycelium

26. Belly rot of cucumber - sunken lesion on the lower surface of fruit

27. Root-knot of cucumber - root galls on a young plant

28. Root-knot of watermelon - root galls on older plant

29. Cucumber mosaic (CMV) - mosaic in a zucchini squash leaf

30. Cucumber mosaic (CMV) - mosaic symptoms in cucumber fruit

31. Papaya ringspot (PRSV-W) mosaic in a watermelon leaf

32. Watermelon mosaic (WMV-2) - mosaic in a cucumber leaf

33. Zucchini yellow mosaic (ZYMV) - mosaic in melon leaves

34. Tobacco ringspot (TRSV) - chlorotic ringspots in a cucumber leaf

35. Viral complex (TRSV+WMV-2) - severe mosaic and leaf distortion of summer squash

36. Unidentified viral diseases - mosaic and distortion of cucurbit fruits

CRUCIFERS

1. **Bacterial soft rot of cabbage - decay of wrapper and outer head leaves**

2. **Bacterial soft rot of cabbage - decay of core and internal head tissue**

3. **Bacterial soft rot of Chinese cabbage - collapsed plant due to core and internal decay**

4. **Black rot of cabbage - chlorotic V-shaped lesions at the leaf margin**

5. **Black rot of cabbage - chlorotic V-shaped lesions at the leaf margin**

6. **Black rot of cabbage - extensive damage to plants in the field**

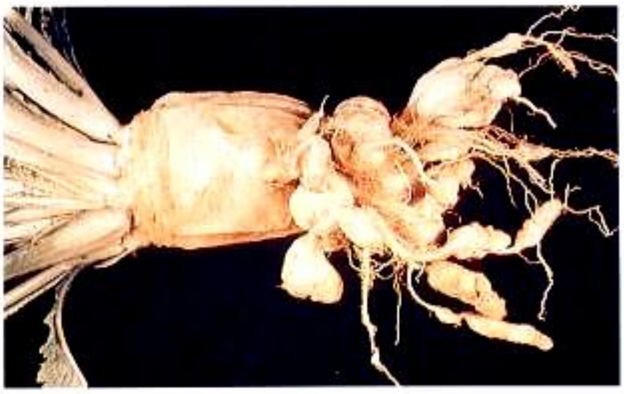
7. **Xanthomonas leaf spot of cabbage - individual and coalescing lesions on a wrapper leaf**

8. **Xanthomonas leaf spot of cabbage - individual and coalescing lesions mostly near leaf veins on the head**

9. **Xanthomonas leaf spot of Chinese cabbage - individual and coalescing spots on a wrapper leaf**

10. **Xanthomonas leaf spot of Chinese cabbage - heavily spotted wrapper leaves and collapsing outer leaves**

11. **Clubroot of cabbage - severely affected root system with numerous spindle-shaped clubs**



12. **Clubroot of horseradish - spindle-shaped clubs on lateral roots**

13. **Fusarium yellows - dull green to yellow leaf discoloration usually on one side that causes leaf twisting**

14. **Alternaria leaf spot of cabbage - large circular lesions with concentric rings on an outer leaf**

15. **Alternaria leaf spot of Chinese cabbage - numerous circular spots on wrapper leaf**

16. **Alternaria leaf spot of Chinese cabbage - close-up of lesions on a wrapper leaf**

17. **Downy mildew of Chinese cabbage - yellow spotting on the upper leaf surface**

18. **Downy mildew of cabbage - downy growth on the lower leaf surface; close-up of fungal sporulation**

19. Downy mildew of broccoli -
internal darkening of a floret from systemic invasion

20. Downy mildew of cauliflower -
internal darkening of a curd from systemic invasion

21. White mold (Watery soft rot) of cabbage -
collapsed outer leaves and head decay with white cottony growth and sclerotia

22. White spot of turnip -
numerous circular light-colored leaf lesions

23. White spot of turnip -
severely damaged foliage

24. Web blight of mustard -
large, irregular, bleached lesions and leaf tattering

25. Web blight of mustard - extensively damaged foliage

26. Turnip mosaic (TuMV) of Chinese cabbage - bright leaf mosaic symptoms

27. Turnip mosaic (TuMV) of Chinese cabbage - necrotic fleck and ringspot symptoms

28. Turnip mosaic (TuMV) of cabbage - necrotic spot and ringspot symptoms

29. Tipburn of cabbage (physiological) - brown internal streaks in a sliced cabbage head

30. Tipburn of cabbage (physiological) - browning of leaf tips inside the cabbage head

GLOSSARY

ACTINOMORPHIC is any of a series of radioactive elements with atomic numbers 89 through 103

AGRICULTURE is the science of farming, including growing plants and raising animals.

ALLELOPATHY is the direct, or indirect, harmful effect of one plant to another through the production of chemical compounds, allelo-chemicals.

ALTERNATE LEAVES OR BUDS is a pattern in which there is one leaf (or bud) per node, and on the opposite side of the stem (not in pairs). *Refer to Figure 1.*

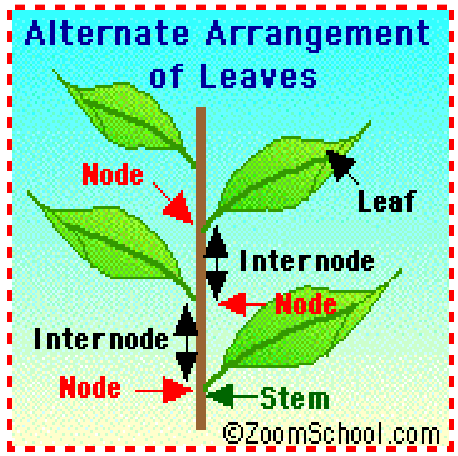


Figure 1

ANGIOSPERM (meaning "covered seed") are flowering plants. They produce seeds enclosed in fruit (an ovary). They are the dominant type of plant today; there are over 250,000 species. Their flowers are used in reproduction. Angiosperms evolved about 145 million years ago, during the late Jurassic period, and were eaten by dinosaurs. They became the dominant land plants about 100 million years ago (edging out conifers, a type of gymnosperm). Angiosperms are divided into the monocots (like corn) and dicots (like beans).

ANNUAL is a plant that goes through its entire life cycle within a year. It grows from a seed, matures, produces seed, and dies within a year.

ANTAGONIST is an organisms that releases toxins or otherwise change conditions so that activity or growth of other organisms (especially pests) is reduced

ANTHER is the tip of a flower's stamen. The anther contains the pollen. *Refer to Figure 2.*

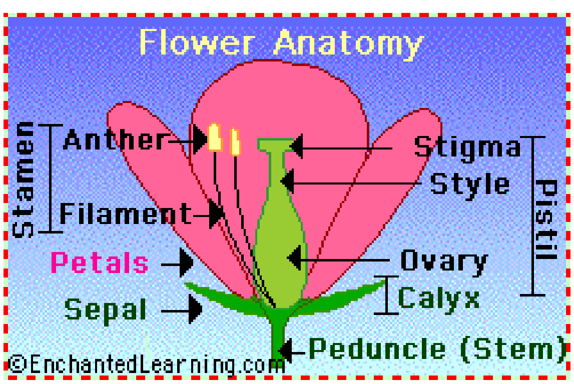


Figure 2.

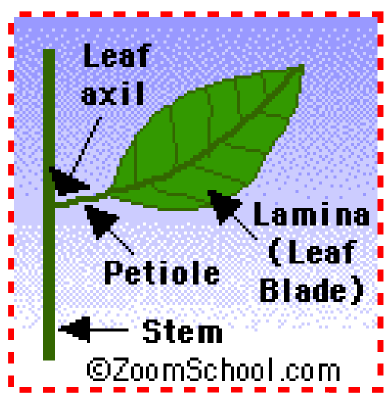


Figure 3.

AUTOTROPH (or producer) is an organism that makes its own food from light energy or chemical energy without eating. Most green plants, many protists (one-celled
2. organisms like slime molds) and most bacteria are autotrophs. Autotrophs are the base of the food chain.

AWN is a bristle-like extension of a plant near its tip.

AXIL of a plant is the angle between the upper side of the stem and a leaf, branch, or petiole. In flowering plants, the bud develops in the axil of a leaf. *Refer to Figure 3.*

AXILLARY BUD
The axillary bud is a bud that develops in the axil (the angle between the stem and the leaf) of a plant.

BENEFICIAL Organisms that provide a benefit to crop production, applied especially to natural enemies of pests and to pollinators such as bees.

BIENNIAL (meaning "two years") means that it takes two years to complete the full life cycle.

BIODIVERSITY is the abundance of different plant and animal species found in an environment.

BIOTIC DISEASE is a disease caused by a pathogen, such as a bacterium fungus, mycoplasma, or virus.

BIOLOGICAL CONTROL is the action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average level than would occur in their absence. Biological control may occur naturally in the field or result from manipulation or introduction of biological control agents by people.

BIOMASS is the total amount of living material in an area. It is calculated by adding up the weights of all of the organisms.

BIPINNATE is a leaf shape; having doubly pinnate leaflets

BLADE is a narrow, flat leaf.

BOTANY is the scientific study of plants.

BOTANICAL is derived from plants or plant parts.

BRACT is a reduced, leaf-like structure that is associated with a flower or a cone.

BUD is a small, developing part of a plant that grows into a flower, a new leaf or a stem.

BUD SCALE is a modified leaf (or similar structure) that covers and protects the bud.

BULB is an underground stem, usually globular, that has fleshy leaves emerging from the top and roots emerging from the bottom. The fleshy leaves store food. Examples include the tulip, narcissus, and onion. *Refer to Figure 4.*

BULBEL (also called a bulbet) is a small bulb that grows from another bulb. This is an example of vegetative propagation.

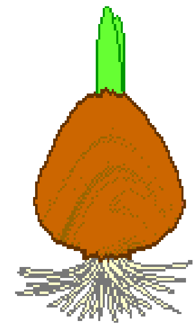


Figure 4.

CALYX is the sepal of a flower. *Refer to Figure 2*.

CAPSULE
A capsule is a seed pod that opens when it is dry and the seeds are mature.

CARBON DIOXIDE CO_2, is a molecule that has one carbon atom and two oxygen atoms; it is a gas at standard temperature and pressure. Plants use carbon dioxide gas in the photosynthetic process.

CARNIVORES are animals that eat meat. They usually have sharp teeth and powerful jaws.

CASPARIAN STRIP is waxy layer (a band of suberin, a waterproofing material) that is located in the walls of plant root cells. This barrier strip stops the transport of water and minerals into the main vascular system of the root.

CEREAL is a grain that is used for human food. Some cereals include rice, oats, wheat, and barley.

CERTIFIED SEED OR PLANTING STOCK are seeds, tubers or young plants certified by a recognized authority to be free of or to contain less than a minimum number of specified pests or pathogens.

CHLOROPHYLL is a molecule that can use light energy from sunlight to turn water and carbon dioxide gas into sugar and oxygen (this process is called photosynthesis). Chlorophyll is magnesium based and is usually green.

COLEOPTILE is a protective sheath that surrounds the shoot tip and the embryonic leaves of the young shoot of grasses.

COMPLETE FLOWER has a stamen, a pistil, petals, and sepals.

COROLLA consists of the petals of a flower.

COTYLEDON is the embryonic leaf within a seed. When a seed germinates, the cotyledon is the first leaf to grow. Monocots have one cotyledon; dicots have two cotyledons.

CROSS-POLLINATION is the transfer of pollen from the anther to the stigma of a flower on a different plant.

CRUCIFORM is shaped like a cross.

CULM is the elongated straw or hollow stem of grasses. The culm usually supports the inflorescence.

CULTIVAR is a plant that is a cultivated (bred) variety.

CUTICLE is the fatty or waxy outer layer of epidermal cells that are above ground.

CYME is an inflorescence where the central flower opens first.

DAMPING-OFF is the destruction of seedlings by one or a combination of pathogens that weaken the stem or root.

DECOMPOSERS are organisms like fungi and some bacteria that break down and digest the remains of organisms.

DECOMPOSITION is the decay or breakdown of things into more basic elements. For example, after a plant dies, it decomposes into organic nutrients.

DEHISCENT is a structure on some plants that opens to release seeds or pollen grains.

DEHISCENT FRUIT splits open when it is mature, causing the dispersal of its seeds. Some dehiscent fruits include cotton, poppy, peanuts, milkweed, magnolia, and all beans.

DICOT (Class Magnoliopsida) is a type of flowering plant (an angiosperm) whose seed has two embryonic leaves (cotyledons). The leaf veins are usually net-like (and not parallel). Taproots are often present. Beans and peas are examples of dicots.

DICHOTOMOUS VENATION is a pattern of leaf veins in which the veins branch in two over and over again. Ferns are dichotomousy veined. A few angiosperms and gymnosperms (like gingkos) have dichotomous venation.

DIOECIOUS has the male and female flowers on different plants (Compare with monoecious). For example, date trees are dioecious.

DISEASE is any disturbance of a plant that interferes with its normal structure, function, or economic value.

DORMANCY is a period in which a plant has no active growth in response to harsh environmental conditions (like droughts or cold seasons).

ECOSYSTEM is the interrelationships between all of the living things in an area.

EMBRYO is a developing plant still inside the seed. The embryo has cotyledons (embryonic leaves), a root cap, a food source and a plumule (shoot), all located inside the protective seed coat.

ENDOSPERM is the tissue containing stored food in a seed that surrounds the embryo and is eventually digested by the embryo as it grows.

ENTIRE LEAF smooth edges (margins) (with neither teeth nor lobes).

EPICOTYL is the part of the stem that is above the first leaves.

EPIDERMIS is the outer protective layer of a plant. This tissue helps prevent injury and minimizes water loss by evaporation.

FAMILY (In classification) is a group of related or similar organisms. A family contains one or more genera (plural of genus). A group of similar families forms an order.

FERTILIZER is material that is added to soil to increase is fertility and output. Fertilizers include manure, compost, and chemical mixtures.

FILAMENT is the part of the flower that holds the anther. *Refer to Figure 2.*

FLOWER is the reproductive unit of angiosperms. Flowers usually have carpels, petals, sepals, and stamens. Some flowers (called perfect flowers) have both male and female reproductive organs; some flowers (called imperfect flowers) have only male reproductive organs (stamens) or only female reproductive organs (ovary, style, and stigma). Some plants have both male and female flowers, while other has males on one plant and females on another. Complete flowers have a stamen, a pistil, petals, and sepals. Incomplete flowers lack one of these parts. *Refer to Figure 3.*

FLOWER BUD is a bud in which flower parts are contained.

FRUIT is the part of a flowering plant that contains the seeds. Some fruits include apples, oranges, berries, maple pods, and acorns. Some fruit are fleshy and some are dry, like cotton (a dehiscent fruit) and sunflower (an indehiscent fruit). Not all fruit are edible. True (simple) fruits (like the tomato, coconut, watermelon, olive, lemon, and banana) develop from the wall of a single ovary. False (compound) fruits (like the strawberry, rosehip, and pineapple) develop from more than one pistil.

FUNGUS (plural fungi) is organisms that obtain energy by breaking down dead organic material and that produce spores. Some fungi include mushrooms, toadstools, slime molds, yeast, penicillin, mold, and mildew. Classification: kingdom Fungus.

GALL is a localized swelling or outgrowth of plant tissue often formed in response to the action of a pathogen or other pest.

GERMINATION is the beginning of growth of a plant from its seed.

GLABROUS surface lacks hairs (and has a smooth surface).

GRAFT is a shoot or bud that has been joined to another plant.

GRAIN is a single particle of pollen.

GUARD CELL is a crescent-shape that control the size of the opening of the stoma using turgor pressure. This changes the amount of water vapor and other gases that can enter and leave the plant. *Refer to Figure 5.*

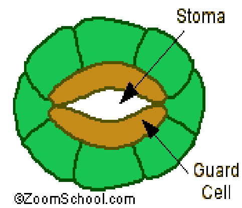


Figure 5.

HABITAT is a space (which includes food, water and shelter) suitable for the survival and reproduction of an organism.

HEAD is the inflorescence of many grass plants, including small grains.

HECTARE is metric unit of area. A hectare is equal to 10,000 square meters.

HERB is a seed plant that does not have a woody stem. Every year, herbaceous plants produce a completely new stem. Herbaceous plants are generally short lived and relatively short (compared to woody plants). Some herbaceous plants include the banana, grasses, and forbs.

HERBIVORES (also called primary consumers) are animals that eat plants.

HERMAPHRODITE is a plant that has both female and male reproductive organs.

HILUM is the scar on a seed coat at the location where it was attached to the plant's stalk during development.

HORMONE is a chemical in plants (and other organisms) that regulates the plant's growth, reproduction, and other functions.

HORTICULTURE is the science of growing fruits, vegetables, flowers, and ornamental plants.

HOST is an organism which a parasite uses for food and/or shelter.

HUMUS is the rich, organic portion of the soil. It is composed of decayed plant and animal materials.

HYBRID is the offspring of two organisms that belong to different breeds, varieties, species or genera.

HYPOCOTYL is the part of the stem of a sprouting plant that is above the root and below the stalk of the cotyledons (seed leaves).

IMPERFECT FLOWER has either male (stamen) and female (ovary) reproductive organs on the same flower, but not both (compare with perfect flowers).

INCOMPLETE FLOWER is missing one of the four major parts of the flower, the stamen, pistil, petals, or sepals.

INDEHISCENT is a fruit that remains closed at maturity is indehiscent. Nuts, acorns, sunflowers, grains, and maple pods are examples of indehiscent fruits.

INDIGENOUS organism is one that lives naturally in a particular region and was not introduced there by man.

INFLORESCENCE is the type of flower in which there is more that one flower in a single structure.

INORGANIC means containing no carbon; generally used to indicate materials (for example, fertilizers) that are of mineral origin.

INSECTIVOROUS organisms eat insects. Insectivorous plants trap and digest insects for nourishment.

INTERNODE is the part of a plant's stem between two nodes is the internode - the distance along the stem between the leaves. *Refer to Figure 1.*

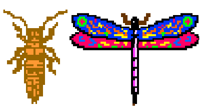


Figure 6.

INSECTS have exoskeletons and six legs. They evolved during the Silurian Period, 438 to 408 million years ago, long before dinosaurs existed. *Refer to Figure 6.*

JUVENILE is in an early phase of plant growth in which it increases in size but has not yet flowered.

LARVA (plural: larvae) is the immature form of insects that develop through the process of complete metamorphosis including egg, several larval stages, pupa, and adult. In mites, the first-stage immature is also called a larva.

LAMINA is the blade of a leaf. *Refer to Figure 3*

LANCEOLATE leaves are shaped like a lance; they have a broad base and taper to a point. *Refer to Figure 7.*

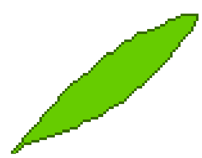


Figure 7.

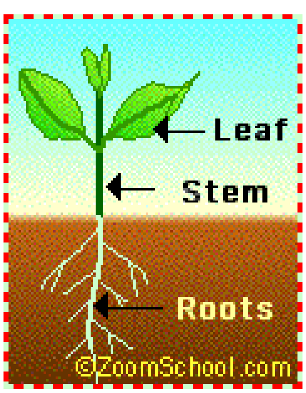


Figure 8.

LEAF is an outgrowth of a plant that grows from a node in the stem. Most leaves are flat and contain chloroplasts; their main function is to make food energy through photosynthesis. The first leaf to grow from a seed is called the cotyledon. *Refer to Figure 8.*

LEAFAXIL is where the petiole of the leaf attaches to the stem. *Refer to Figure 3.*

LEGUME is a flowering plant that bears its protein-rich seeds in pods and can fix nitrogen from the soil (due to the symbiotic root bacteria, rhizobia). Some legumes include lentils, beans, clover, alfalfa, lespedezas, vetches, kudzu, and peas. Classification: Kingdom Plantae, class Magnoliopsida, order Rosales, family Leguminosae.

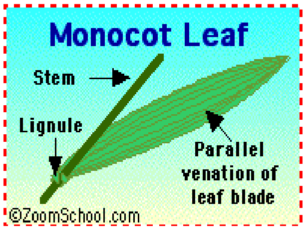


Figure 9.

LIGNULE (which means tongue) are the two small flaps at the base of a monocot's leaf that wrap around the stem. *Refer to Figure 9.*

LOAM is a type of rich, crumbly soil that contains an almost equal amount of sand and silt, plus a smaller amount of clay (it contains from 28 to 50% silt, less than 52% sand, and 7 to 27% clay).

LOCULES are compartment or cavity of an ovary, anther, or fruit.

LODGING is the toppling of plants of a grain crop before harvest, often from wind, rain, or waterfowl.

LONGITUDINAL STRIATE VENATION is a vein pattern found in monocots leaves. A leaf with longitudinal striate venation has its veins arranged almost parallel to one another, running the length of the leaf (also called parallel venation).

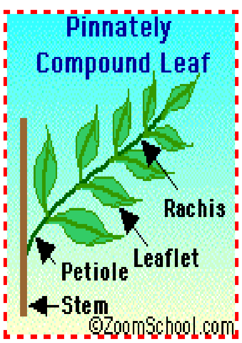


Figure 10.

MERISTEM is a group of plant cells that can divide indefinitely. It provides new cells for the plant.

MIDRIB
The midrib (rachis) is the central rib of a leaf. It is usually continuous with the petiole and is often raised above the lamina (the leaf blade). On a compound leaf, the midrib extends from the first set of leaflets (where the petiole ends) to the end of the leaf.

MILDEW is a parasitic, filamentous fungus that grows on a host plant.

MOLD is a type of fungus (and not a plant). Like other fungi, molds do not contain any chlorophyll (and cannot make their own food); molds live off the food produced by plants or animals, or decaying matter. Molds are often parasites on plants, animals, or even other fungi. Molds reproduce with spores. Some molds spoil our food, but other foods are produced by the action of mold (for example, blue, Roquefort, and Camembert chesses have mold growing in them, giving them their flavor). The anti-bacterial drug penicillin is made from the Penicillium mold (Alexander Fleming discovered penicillin in 1928). Classification: Kingdom Fungi, Division Eumycota (septate fungi), Classes Hyphomycetes, Oomycetes, and Zygomycetes.

MONOCOT is a type of flowering plant (an angiosperm) whose seed has one embryonic leaf (cotyledon). The leaves of monocots generally have parallel venation (the veins are parallel to one another). The roots of monocots are usually fibrous and the flower parts are often in multiples of three. *Refer to Figure 9*.

MONOCULTURE is a system of agriculture in which a single type of crop is grown in an area.

MONOECIOUS plants have the male and female reproductive organs on the same plant.

MORPHOLOGY is the study of the external structure of organisms (for example, the arrangement of leaves on a plant).

MULCH is a layer of material placed on the soil surface to prevent weed growth.

MYCORRHIZAE is a fungus that grows in a symbiotic relationship with the roots (or rhizoids) of a plant.

NATURAL ENEMIES are Predators, parasites, or pathogens that are considered beneficial because they attack and kill organisms that we normally consider to be pests.

NECTAR is the sweet liquid produced by many flowers. Nectar attracts many insects (like butterflies and bees) who go from flower to flower sipping nectar, causing the pollination of the flowers.

NITROGEN FIXING. Some bacteria (rhizobia) are nitrogen-fixing; they transform nitrogen gas in the atmosphere into a form that can be used by plants.

NODE is a part of the stem of a plant from which a leaf, branch, or aerial root grows. *Refer to Figure 1*.

NODULE is a small, rounded knot on some leguminous plant roots which contain nitrogen-fixing bacteria (rhizobia). For example, peanut plant roots have nodules.

NOXIOUS WEEDS are plant that is considered by local authorities to be a problem, growing where it is not wanted.

NUTRIENT is a chemical that an organism needs to ingest in order to survive (like fats, carbohydrates, vitamins, minerals, etc.).

ORDER. In Linnean classification, an order is a group of related or similar organisms. An order contains one or more families. A group of similar orders forms a class.

ORGANIC is a material (e.g. pesticide) whose molecules contain carbon and hydrogen atoms. Also may refer to plants or animals which are grown without the use of synthetic fertilizers or pesticides.

OVOID or egg-shaped; having the solid form of an egg.

OVULE is the female reproductive cell of flowering plants and cone-bearing plants. After the ovule is fertilized by the male pollen, the ovule becomes a seed.

PALMATE leaf has a hand-like structure. It has more than three lobes that branch from a single point at the base of the leaf. *Refer to Figure 11.*

PALMATE VENATION has the main veins arising from a point at the base of the leaf. *Refer to Figure 12.*

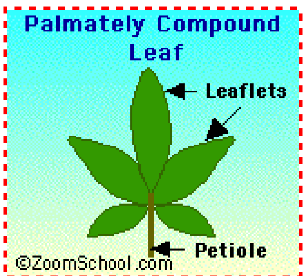


Figure 11

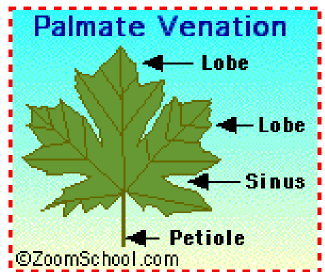


Figure 12.

PARASITE is an organism which uses its host for food and/or shelter. A parasite gives its host nothing in return and often makes it sick or even kills the host. Termites are a parasite of many trees.

PARASITISM is a relationship between two organisms in which one organism benefits at the other organism's expense. Lice are an example of a parasite that affects many animals; termites are parasites that are destructive to many trees. Parasitism is a type of symbiosis.

PARTED (also called cleft) leaf is one in which the margins between the irregular teeth go more than halfway to the midrib. *Refer to Figure 13.*

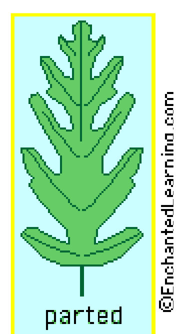


Figure 13.

PEAT is a type of soil that is composed of incompletely decomposed plant material that water-logged and low in oxygen.

PEDICEL is plant stalk that attaches a single flower or fruit to the main branch of the inflorescence.

PERENNIAL has a life cycle that lives for more than two years. Perennials usually flower each year.

PERFECT FLOWER has both male (stamen) and female (ovary) reproductive organs on the same flower. (Compare with imperfect flowers.) *Refer to Figure 2.*

PERIANTH (which means "around the anthers") is the sepals and petals of a flower.

PERICARP is the fruit wall that develops from the ovary wall. The pericarp is divided into the endocarp, mesocarp and exocarp.

PERICARPAL is the upper part of the flower stem, the receptable, and the lower part of the pistil.

PETAL is one of the leafy structures that comprise a flower. Petals are often brightly-colored and have many different shapes. They are located between the sepals and the flower's reproductive organs.

PETIOLATE means having a petiole.

PETIOLE is a leaf stalk. On a compound leaf, the petiole extends from the stem to the first set of leaflets. A leaf without a petiole is sessile. *Refer to Figure 3.*

pH is a value used to express relative acidity or alkalinity.

PHEROMONE is a substance secreted by an organism to affect the behavior or development of other members of the same species; sex pheromones that attract the opposite sex for mating is used in monitoring certain insects.

PHLOEM is the food-conducting tissue of a plant, made up of sieve tubes, companion cells, phloem parenchyma, and fibers.

PHLOEM FEEDING is an organism that withdraws nutrients from the food-conducting tissue of a plant's vascular system.

PHOTOSYNTHESIS is the process by which plants convert sunlight into energy.

PHYLLOCLADE is a flattened stem that looks like a leaf.

PHYLLODE is a leaf that has an enlarged midrib and no blades.

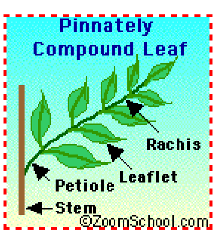


Figure 14.

PINNATE COMPOUND LEAF is made up of many small leaflets arranged in pairs on either side of a long central midrib (the rachis). There is often a single terminal leaflet at the end of the midrib. *Refer to Figure 14.*

PINNATELY LOBED LEAVES have many lobes arranged along the midrib. *Refer to Figure 15.*

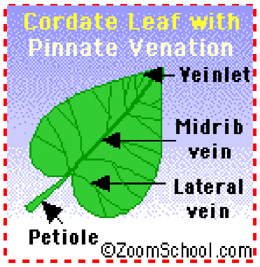


Figure 16.

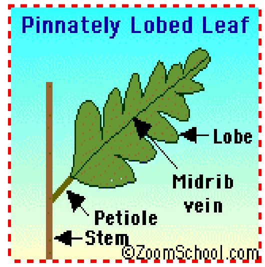


Figure 15.

PINNATE VENATION is a character of a leaf with pinnate venation has its veins arranged in pairs coming from a main central midrib vein (the rachis). *Refer to Figure 16.*

PISTIL is the female part of the flower, usually consisting of ovules, ovary, style, and stigma.

PISTILLATE flowers have a pistil or pistils.

PLANT is a member of the kingdom Plantae, a living organism that undergoes photosynthesis.

PLUMULE is the shoot of a plant embryo (in the seed before germination).

POD is an elongated, two-sided vessel that contains several fertilized seeds. It is a dehiscent fruit or pedicarp - the pod splits open when the seeds are mature. Beans and peas are some plants that have pods.

POLLEN is the male reproductive cell of flowering plants and cone-bearing plants. Pollen grains are produced in the anther of a flower.

POLLINATION is the transfer of pollen from the anther to the stigma.

POLLINATOR is the agent of pollen transfer, usually bees.

POLLINIZER is the producer of pollen; the variety used as a source of pollen for cross-pollination.

POST EMERGENCE HERBICIDE is an herbicide applied after the emergence of weeds.

PREDATOR is any animal (including insects and mites) that kills other animals (prey) and feeds on them.

PRE EMERGENCE HERBICIDE is an herbicide applied before emergence of weeds.

PRIMARY ROOT is the first root of a plant to develop in the germinating seed. The primary root develops from the radicle of the embryo. It is also called the taproot.

PRODUCER (or aurotroph) is an organism that makes its own food from light energy (using photosynthesis), or chemical energy (using chemosynthesis). Most green plants, many protists (one-celled organisms like slime molds) and most bacteria are producers. Producers are the base of the food chain.

PULSE refers to a leguminous plant that produces edible seeds or to the seeds themselves. Some pulses include peas, beans, and lentils.

RACHIS is the midrib of a leaf. It is usually continuous with the petiole and is often raised above the lamina (the leaf blade). On a compound leaf, the rachis extends from the first set of leaflets (where the petiole ends) to the end of the leaf. *Refer to Figure 17.*

Figure 17.

RADICLE is the lower part of an embryo's axis. The radicle develops into the primary root.

RECEPTACLE is the terminal portion of the flower stalk.

RETICULATE VENATION
A leaf with reticulate venation has its veins arranged in a pattern such that larger veins give rise to progressively smaller veins. The end branches of the veins define small areas called aeroles.

RHIZOBIA are bacteria that live symbiotically with plants (especially legumes), living on the plant's roots. The rhizobia fix nitrogen (from atmospheric nitrogen) for the plant and the rhizobia get energy from the plant. *Refer to Figure 18.*

Figure 18.

RHIZOME is a horizontal, underground shoot, especially one that forms roots at the nodes to produce new plants.

ROOT is a plant structure that obtains food and water from the soil, stores energy, and provides support for the plant. Most roots grow underground. *Refer to Figure 8.*

ROOT CAP is a cap-shaped structure at the ends (tips) of the roots. It covers and protects the apical meristem (the actively growing region) of the root. *Refer to Figure 19.*

ROOT HAIRS are very thin, hair-like roots that are extensions of the root's epidermis. Root hairs have a large surface area and absorb water and minerals for the plant. *Refer to Figure 19.*

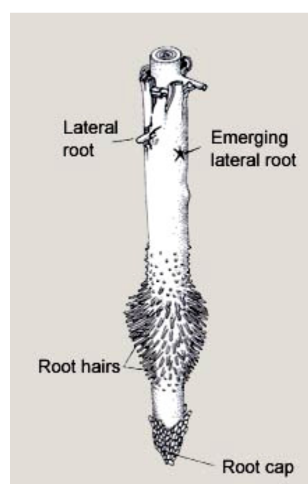


Figure 19.

ROOT TIP is the tip of the root and contains the root cap and the apical meristem (the actively growing region). *Refer to Figure 19.*

ROGUE means to remove diseased plants from a field.

ROTATION is the practice of purposefully alternating crop species grown on the same plot of land.

ROW COVERS is any fabric or protective covering placed over rows of plants to protect them from pest damage or harsh climate.

RUE LEAF is any leaf produced after the seed leaves (cotyledons).

RUNOFF is water that drains or flows from the land into streams and rivers, eventually into seas. The water is generally from rain or snow pack melt.

SANITATION is any activity that reduces the spread of pathogen inoculums, such as removal and destruction of infected plant parts, cleaning of tools and field equipment.

SECONDARY BLOOM
A second production of flowers on a potato plant, occurring at the end of the mainstem of an indeterminate cultivar; secondary bloom may occur on a determinate cultivar at leaf axils along the mainstem.

SECONDARY ROOTS is the network of fine roots that develops from the primary roots of a strawberry plant and picks up water and nutrients from the soil; white roots.

SEED is the reproductive unit of some plants.

SEED COAT also called "Testa" is the outer, protective layer covering the seed. The seed coat is formed from the two integuments in the developing seed.

SEED LEAF is the leaf formed in a seed and present on a seedling at germination; cotyledon.

SELF FRUITFUL is the ability to set fruit with pollen from the same flower or tree.

SEPAL is one of the outermost flower structures which usually enclose the other flower parts in the bud. *Refer to Figure 2.*

SEED POD is an elongated, two-sided vessel that contains several fertilized seeds. It is a dehiscent fruit or pedicarp - the pod splits open when the seeds are mature. Beans and peas are some plants that have pods.

SERRATED LEAVES have a jagged edge. *Refer to Figure 20.*

SESSILE is a leaf without a petiole (a leaf stalk) is sessile.

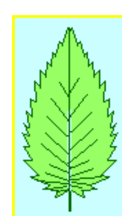


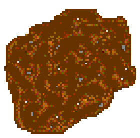
Figure 20.

SHIFTING CULTIVATION is a type of farming in which fields are used for a few years, and are then left to grow in a wild state for many years. This allows the soil to recover and become rich and fertile again.

SHOOT is new growth on part of a plant.

SIMPLE LEAF is a leaf with only one lamina for each petiole (that is, each leaf blade has one stem). *Refer to Figure 3.*

SIDE DRESSING is Fertilizers or other materials added to the soil around a growing crop.



SOIL is a natural, constantly-changing substance that is made up of minerals, organic materials, and living organisms. Plants grow in soil. *Refer to Figure 21.*

Figure 21.

SOLAR RADIATION is the heat and light that comes from the sun.

SP is an abbreviation for "species." Sp. is often used when the genus is known, but the species is not.

SPIKE is a flower stalk, an ear of grain (such as corn or wheat), or an inflorescence of unstalked flowers. *Refer to Figure 22.*

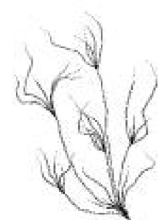


Figure 22.

SPIKELET is a secondary spike found in grasses; it is a cluster of two or more flowers in the inflorescence. *Refer to Figure 23.*

SPORE is a single-celled reproductive unit of some organisms (cryptogams like mushrooms, ferns and mosses). Functionally, a spore is similar to a seed but it does not contain an embryo). Spores are usually encapsulated by a rigid wall.

SPROUT is a very young plant (newly germinated) or the new growth on a plant (a shoot).

STAMEN is the male reproductive part of a flower. It consists of the filament and the anther, which produces pollen.

STEM is the axis of a plant; it may be above or below the ground. *Refer to Figure 8.*

STIGMA is part of the pistil, the female reproductive tissue of a flower. The stigma receives the male pollen grains during fertilization.

STIPULES are small, paired appendages (sometimes leaf-life) that are found at the base of the petiole of leaves of many flowering plants.

STOLON is an above-ground stem that has buds that sprout to form new shoots, forming a new, genetically-identical plant. Strawberry plants have stolons.

STRIATE VENATION is a vein pattern found in monocot leaves. A leaf with striate venation has its veins arranged almost parallel to one another. *Refer to Figure 9.*

STYLE is part of the pistil, the female reproductive tissue of a flower. The style is a long tube on top of the ovary below the stigma. After the male's pollen grains have landed on the stigma during fertilization, pollen tubes develop within the style. The pollen tubes transport the sperm from the grain to the ovum (where fertilization of the egg occurs and the seeds will develop).

SYMBIOSIS is a situation in which two dissimilar organisms live together. There are many types of symbiosis, including mutualism (in which both organisms benefit), commensalisms (in which one organism benefits and the other is not affected), or parasitism (in which one organism benefits at the expense of other organism). Symbiosis is used to be defined as a situation in which two dissimilar organisms live together to the benefit of both - this is now called mutualism. The word symbiosis means "living together"" in Greek.

TAP ROOT is the main root of some plants; the tap root extends straight down under the plant.

TERMINAL is the growing tip of a stem, especially the main stem.

TERMINAL SPIKELET STAGE is a stage in the development of the wheat spike when the primordia of the terminal spikelet are formed.

TERMINAL BUD is a bud located at the apex (tip) of the stem. This type of bud is the dominant bud, since it can cause all the lateral (side) buds below it to remain dormant at all times of the year. Terminal buds have special tissue called apical meristem, which are cells that can divide indefinitely.

TESTA is the seed coat. It covers the seed.

THIGMOTROPISM is the directional bending or turning response of a plant upon contact with a solid surface or object; it is basically a sense of touch in plants. For example, the tendrils of vines are thigmotropic.

THORN is a sharp, modified stem. Thorns have a stem-like vascular structure. The honey locust plant has thorns.

TOP CROP is a fruit produced in the second fruiting cycle of cotton, mainly on upper branches.

TRUE LEAF is any leaf produced after the cotyledons.

TRANSPIRATION is the process in which plants lose water through pores in their leaves (these openings are called stomata). As water is lost from the plant, the plant takes up more water (and minerals) through its roots. The rate of transpiration varies as the conditions of the plant change and is controlled by the opening and closing the stomata.

TUBER is a modified root that stores nutrients. Potatoes are tubers.

VARIETY is an identifiable strain within a species, usually referring to a strain which arises in nature as opposed to a cultivar which is specifically bred for particular properties; sometimes used synonymously with cultivar.

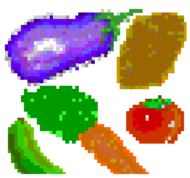


Figure 25.

VEGETABLE is a plant whose stem, leaves, tubers, roots, bulbs, or flower is a food source for people. Some examples of vegetables include carrots, eggplant, potatoes, spinach, broccoli, onion, and asparagus. *Refer to Figure 25.*

VEGETATION is all of the plant life found in an area.

VEGETATIVE PROPAGATION is a method of reproducing asexually; the offspring have the same genetic makeup as the parent.

VEGETATIVE STATE is the stage in a flowering plant's life cycle before the appearance of its fruiting structures.

VEIN is a vascular structure (xylem and phloem cells surrounded by the bundle sheath) in a leaf that provides support for the leaf and transports both water and food. The veins on monocots are almost parallel to the margins of the leaf. The veins of dicots radiate from a central midrib. *Refer to Figure 3.*

VEINLET is a small vein. Veinlets are located toward the margins of the leaf. *Refer to Figure 16.*

VENATION is the arrangement of veins in a leaf. Some different venation patterns include pinnate, palmate and parallel. *Refer to Figure 12.*

VINE is a plant that needs support as it grows. Some vines grow by twining around other objects for support (e.g., morning glory), some use tendrils (modified shoots) to attach to objects (e.g., peas and vetch), and others send out aerial roots, often with suckers (e.g., poison ivy). *Refer to*

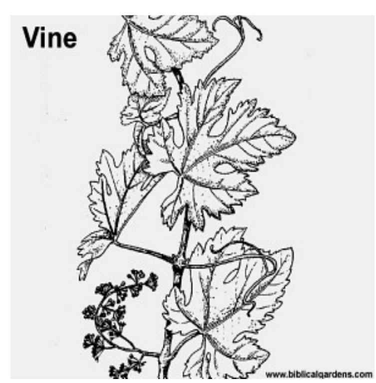


Figure 26.

Figure 26.

VIRUS is a very small organism that can multiply only within living cells of other organisms and is capable of producing disease symptoms in some plants and animals.

XYLEM is a Plant tissue that conducts water and nutrients from the roots up through the plant.

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