DOCUMENT RESUME

ED 241 777		CE 038 581

TITLE	Crop Production Handbook for Peace Corps Volunteers. Appropriate Technologies for Development. Reprint R-6.
SPONS AGENCY	Peace Corps, Washington, DC. Information Collection and Exchange Div.
PUB DATE	Sep 82
CONTRACT	PC-73-1034
NOTE	155p.; Prepared by Development and Research Corp.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Agricultural Education; *Agricultural Production; *Agricultural Skills; Agricultural Supplies; Agriculture; *Agronomy; Botany; Definitions; Entomology; Fertilizers; *Field Crops; *Grains (Food); Guidelines; Harvesting; Herbicides; Insecticides; *Land Use; Pesticides; Pests; Plant Growth; Plant Pathology; Postsecondary Education; Soil Conservation; Soil Science; Vocational Education; Voluntary Agencies; Volunteers; Volunteer Training; Weeds

ABSTRACT

This manual, prepared for use by Peace Corps volunteers, provides background information and practical knowledge about crop production. The manual is designed to convey insights into basic crop production, principles, and practices. Primary emphasis is given to providing explanations and illustrations of soil, plant, and water relationships as they affect crop production. The content is presented in as nontechnical language as possible. Each of the seven units of the text are complete, substantially self-contained, and provide information, tables, and illustrations. The units cover the following topics: soils, plants, entomology, cereal crops, pulse crops, sugar and fiber crops, and oil crops. A glossary of terms used in agronomy completes the manual. (KC)

INFORMATION COLLECTION & EXCHANGE

Peace Corps' Information Collection & Exchange (ICE) was established so that the strategies and technologies developed by Peace Corps Volunteers, their co-workers, and their counterparts could be made available to the wide range of development organizations and individual workers who might find them useful. Training guides, curricula, lesson plans, project reports, manuals and other Peace Corps-generated materials developed in the field are collected and reviewed. Some are reprinted "as is"; others provide a source of field based information for the production of manuals or for research in particular program areas. Materials that you submit to the Information Collection & Exchange thus become part of the Peace Corps' larger contribution to development.

Information about ICE publications and services is available through:

Peace Corps
Information Collection & Exchange
Office of Program Development
806 Connecticut Avenue, N.W.
Washington, D.C. 20526

Add your experience to the ICE Resource Center. Send materials that you've prepared so that we can share them with others working in the development field. Your technical insights serve as the basis for the generation of ICE manuals, reprints and resource packets, and also ensure that ICE is providing the most updated, innovative problem-solving techniques and information available to you and your fellow development workers.

Peace Corps

CROP PRODUCTION HANDBOOK

FOR

PEACE CORPS VOLUNTEERS

Prepared for the United States Peace Corps

by

Development and Resources Corporation

In Accordance With Contract PC-73-1034

Peace Corps
Information Collection and Exchange
Reprint R-6
March 1969
March 1976
September 1977
June 1979
September 1982

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

This manual has been prepared for use by Peace Corps Volunteers as a resource in gaining understanding and knowledge concerning crop production. It is intended as a practical handbook containing data pertinent to the needs of Volunteers as those needs have been observed by Development and Resources Corporation staff. Subject areas have been limited to those observed as being of most frequent interest to Volunteers in their project activities in agricultural programs.

This manual is designed to convey insights into basic crop production principles and practices. Primary emphasis is given to providing explanation and illustration of soil, plant, and water relationships as they affect crop production. Care has been taken to make the content realistic and meaningful and to present it with as non-technical a vocabulary as is possible.

Each of the seven units of this text are complete and substantially self contained. Each unit may be used by Volunteers as a review or as new material. While the units provide tables, illustrations and useful information, it is recognized that some of the material presented would be meaningless, or at least inadequately understood by the average generalist, without some agricultural experience. With the aid of this manual, during and after training, a Peace Corps Volunteer should be able to understand and apply the basic agricultural principles for increased production of select crops.

Development and Resources Corporation sincerely hopes that Peace Corps Volunteers will find this manual a useful working tool and helpful in their project activities.

UNIT I - SOILS

A. INTRODUCTION

Soil is a living body covering the surface of the earth consisting of weathered rocks or mineral matter, organic matter, water, air and living organisms. Soil is the medium for the growth of all food and fodder crops. Soil offers mechanical support, air, water and essential plant food nutrients for plant growth. It consists of approximately 50 percent solids, 25 percent air, and 25 percent water. A large population of living organisms is dispersed throughout the entire mass.

Every soil has a characteristic morphology or profile in the field. A succession of layers extend down into loose weathered rock. These layers are known as horizons. The horizons differ in one or more properties such as color, texture, structure, consistency, porosity and reaction. A vertical section exposing the horizons is called a soil profile.

B. SOIL FORMATION

The major steps in the formation of soils are accumulation of soil parent materials and differentiation of horizons in the profile.

The weathering of rocks provides soil parent material. Solid rocks disintegrate slowly under the influence of climate. Temperatures, rainfall and air movement all tend to weaken the rock structure. The minerals in the rocks react with water and air that enter through tiny cracks and crevices. Changes in the minerals then set up stresses which further weaken the rock structure. The final effect of these forces is to break a rock into small pieces. Gradually rocks disintegrate and decay. The loose and weathered rock materials may then become soil parent materials. A mantle of weathered rock known as the regolith now blankets the land surface. This regolith has been formed in some places by disintegration and decomposition of rocks on the spot. In many more places, it has been moved about by water, wind, or ice. The composition and thickness are important to soil formation. The nature of the original rock and the stage of weathering of the regolith affect the fertility and water relationships of soils.

Plants soon begin to gain a foothold in this new soil. Sometimes they begin growing on rock before it has completely disintegrated. Many simple plant forms such as lichens and funit, begin growing. Larger and more complex plants soon follow. Small animals then join the biological community in this infant soil. As these organisms grow and die, their bodies are left on and in the regolith. Parts of dead plants fall to the surface. Roots are left within the weathering rock mass. The addition and decay of organic matter gradually change the character and appearance of the surface layer of this regolith or new soil. It begins to differ from the deeper layers. It thus becomes what is known as the "A" horizon marking the first stage of the differentiation of horizons.

Horizons are formed in soil profiles because of gains, losses and alterations. Organic matter is usually added to the surface layer in greater quantities than to deeper ones. Gains in organic matter are an early step in the differentiation of horizons in most soils. Water also makes possible the differentiation of soil horizons. Water may leach some of the elements and minerals from the top of the "A" horizon into lower horizons. This water usually comes from falling rain. Once in the soil, the water dissolves minute quantities of mineral and organic matter. These dissolved substances move with the water.

The five major factors in soil formation are:

1. Climate. Perhaps the greatest influence upon soil development is climate. Climate can be divided into two categories -- temperature and precipitation. With an increase in temperature, chemical reactions increase. The rate of weathering, therefore, increases with increasing temperature. The amount and type of precipitation greatly influences the acidity or alkalinity of a soil. In general, acid soils occur in regions where the annual rainfall is greater than 15 - 20 inches per year. It is important to know if the rainfall is seasonal or distributed throughout the year. It is also important to know if the rainfall occurs as a general mist or a deluge. Because climate is so important to soil formation, the broad soil regions of the world tend to follow the distribution of climate.

2. Organic Material. Plants, animals, insects, bacteria, and fungi are important in soil formation. Gains in organic matter in the soil, gains or losses in plant nutrients and variations in structure are among the changes that result from living organisms. The types of plants largely determine the kind and amount of organic matter that go into a soil under natural conditions. Some plants add to the soil with falling leaves or fibrous roots while others take their nitrogen from the air and add it to the soil as they die. The bacteria and fungi that live on plant and animal residues, break down complex compounds into simpler forms as in the decay of organic matter.

3. Parent Material. This is sometimes called a passive factor in soil formation. Rocks must be weathered to form parent materials.

These are further changed as horizons develop in a soil profile. The composition and structure of rocks strongly influence the rate of weathering and the products of that weathering. These, in turn, are important to the kind of soil that may be formed.

4. Topography. Topography or the lay of the land affects run-off and drainage. Run-off is generally greater on steep slopes than on small or moderate ones. The amount of water that moves into the soil depends partly upon topography. If the slopes are steep, run-off will be greater and relatively little water is taken into the soil. Run-off on steep slopes usually removes soil.

5. Time. Time is required for soil formation. The amount of time depends on where the processes must start. The development of soil from freshly exposed and fairly pure limestone takes a long time. Other types of stone dissolve much faster.

As a rule, more time is needed for the accumulation of soil parent materials than for the differentiation of the horizons in the profile. Because of weathering during the past centuries, a regolith now exists over all of the continents. Soils have been formed on most land surfaces many times since molten lava first crystallized into rock many years ago.

None of the five factors of soil formation are uniform over the face of the earth. Variations are wide. There are many climates, many combinations of living organisms, many kinds of rocks, many topographies, and many different ages of land surfaces. As a result, there are hundreds of thousands of different local combinations of factors that affect soil formation.

C. SOIL CLASSIFICATION

Differences exist in the soil found in small geographic areas. Every farm consists of several different soils usually referred to as soil types. A single farm may have three to six types of soils within its boundaries. Each one occurs in a definite geographic region and in certain patterns. Regional soils differences are related to the distribution of climate and living organisms. In some places, these variations reflect differences in topography, age of land surfaces, or character of parent rocks. There are also soil variations in such qualities as fertility, tilth, ability to hold available moisture, and susceptibility to erosion.

Throughout the world, six broad soil belts are outlined on a soil map of the earth. These are classified as:

1. Mountain Soils. This belt consists of mountains and similar rough landscapes in which many of the soils are stoney and/or shallow.

2. Tundra. The tundra region has a cold climate which restricts biological activities and horizon differentiation. The soils are frozen for a large part of each year. The deep regolith is permanently frozen in some parts of the tundra.

3. Podzols. Podzolic soils dominate a broad belt in the higher latitudes of the northern hemisphere and some smaller areas in the southern half of the world. Podzolic soils are strongly weathered and leached. They are commonly acid, low in bases such as calcium, and low in organic matter. Levels of fertility are moderate to low. Available moisture capacity is variable depending on depth of soil and textures of horizons. As a group, the soils are responsive to scientific management.

4. Latosols. These soils dominate equatorial belts of Africa and South America. They are also dominant in parts of Asia and North America as well as Australia and the larger islands of the Western Pacific Ocean. These soils are strongly weathered and leached. In fact, they are the most strongly weathered soils in the world. Despite being strongly weathered and deep, most of the soils lack distinct horizons. Red and yellow profile colors are common to latosolic soils due to the large amounts of ironoxides formed through intense weathering. Available plant nutrients are generally low when these soils are used without benefit of modern science.

5. Chernozems. These soils have been formed under prairie or grass vegetation in climates humid to semiarid and temperate to tropical. They include the great soil groups known as prairie soils and chestnut soils. In tropical and subtropical regions these are known as black cotton soils, regurs or dark clay. Generally, these soils have dark "A" horizons of great thickness. They are also the most productive soils as they are much higher in organic matter, have less alkalinity, and are lower in bases than the desert soils. Available moisture holding capacities of the soils are usually moderate to high. These are generally the most fertile soils in the world. Chernozem soils of tropical and subtropical zones often have unfavorable physical properties for tillage and plant growth. They are high in clay content and subject to shrinking and swelling. Their productivity under poor management is low, but they respond well to good management practices.

6. Desert Soils. These soils have been formed under mixed shrub and grass vegetation in arid climates, ranging from hot to cold. These soils are prominent in the great deserts of Africa, Asia

and Australia, and in some of the smaller deserts of North and South America. Desert soils are slightly weathered and leached. The shortage of moisture which restricts weathering and leaching also limits plant growth leaving the soils low in organic matter and nitrogen. The limited rainfall also causes the shallow profiles normal in desert soils. Levels of nutrient elements other than nitrogen are usually moderate to high. There are differences in the productivity depending upon the use to which these soils are put.

D. SOIL - WATER RELATIONSHIPS

A soil, in order to function as a medium for plant growth, must contain a certain amount of water. This moisture promotes the chemical and biological activities of the soil. The moisture acts as a solvent, carrier of nutrients, and functions as a nutrient. The amount, kind and control of the soil moisture must be considered in any study of soil and plant relationships. The productivity of a soil is often a direct function of its water holding capacity.

Precipitation, which falls in the form of rain or snow, must be absorbed and retained by the soil to benefit plants. Soil water behaves differently according to the tightness with which it is held by the soil. When the water film surrounding a soil particle is thick enough, the attraction of the soil for the water in the outer edges of the film will be so slight that the outer water will be subject to the influence of gravity.

Four forms of soil water are usually recognized. These are:

1. Gravitational Water. Gravitational water percolates downward through the subsoil by the force of gravity and drains away.

2. Capillary Water. Capillary water is held by the soil against the pull of gravity. It can move to a certain extent in any direction in response to capillary tension. This form of water can be removed by air drying and, to a certain extent, by plant absorption.

3. Hygroscopic Water. Hygroscopic water is that water which is retained by an air dry soil. It can be removed only by oven drying for several hours at a temperature of 105° centigrade.

4. Combined Water. This remains after hygroscopic water has been removed. It is held in chemical combination and is driven off only when subjected to high temperatures.

Since the free or gravitational water rapidly drains away from the root zone in well drained soils, it is not normally available for plant use. Of the capillary water that remains, the amount available to the plant is that which is in excess of the wilting point. The wilting point is the percentage of water remaining in the soil at the time permanent wilting occurs. At the wilting point, there is still some capillary water present in the soil but it is held with such tension that it cannot be removed by the plant.

The movement of water by capillary action is affected by anything which affects the size and continuity of the pores. Water will rise faster above the water table in a coarse textured soil in the early stages but it will eventually rise to a greater height in a fine textured soil. Movement of water by capillary action is faster through a wet soil than through a dry soil.

The amount of water that a given soil can hold is a function of the number and size of the individual pores rather than the total amount of pore space. Thus, a coarse or sandy soil will not hold as much water as a fine textured clay soil.

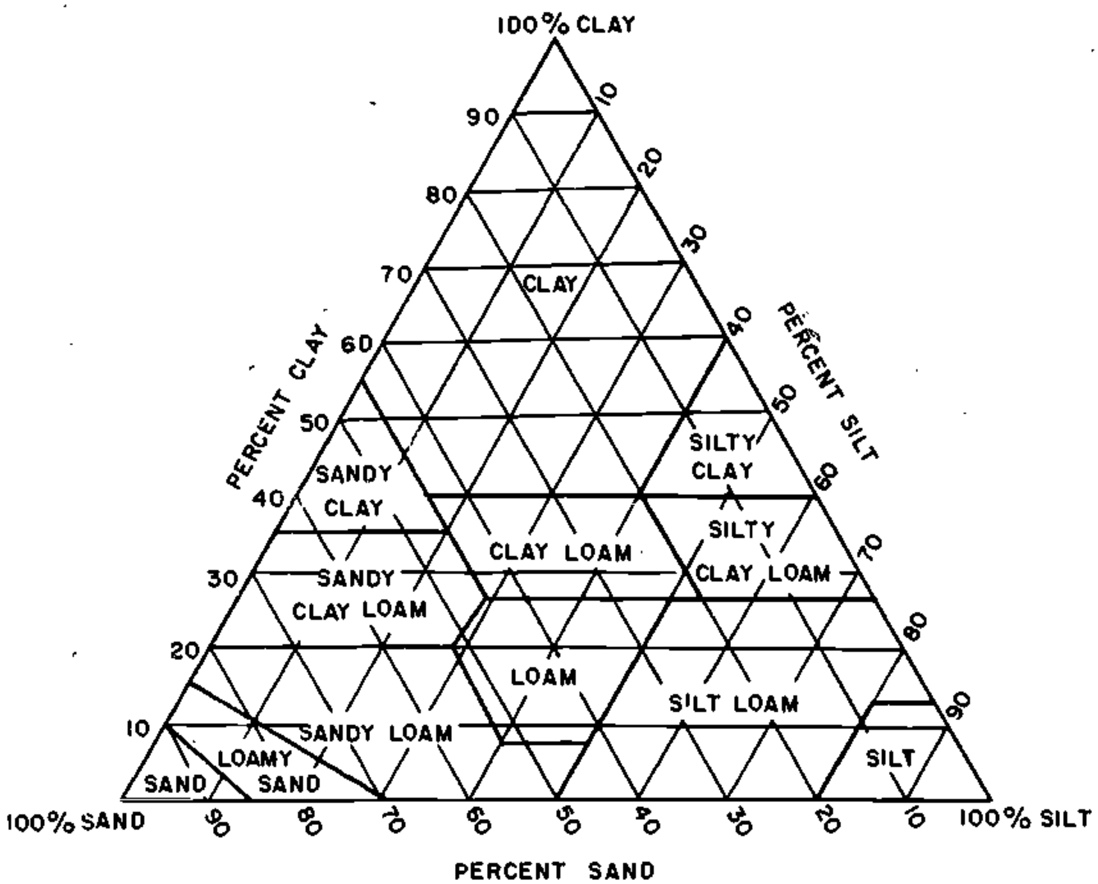
When all of the pore space of a soil is filled with water, it is said to be saturated. When a soil contains the maximum amount of the water that it can hold against the force of gravity, it is said to be at field capacity.

A good rule of thumb for medium textured soils is that the field capacity is approximately one-half the maximum retentive capacity and the permanent wilting point is approximately one-half of the field capacity.

Soil moisture is very important to plant growth because nutrients that a plant takes into its system for growth, go into solution with water before the plant can utilize these nutrients as plant food.

E. PHYSICAL PROPERTIES

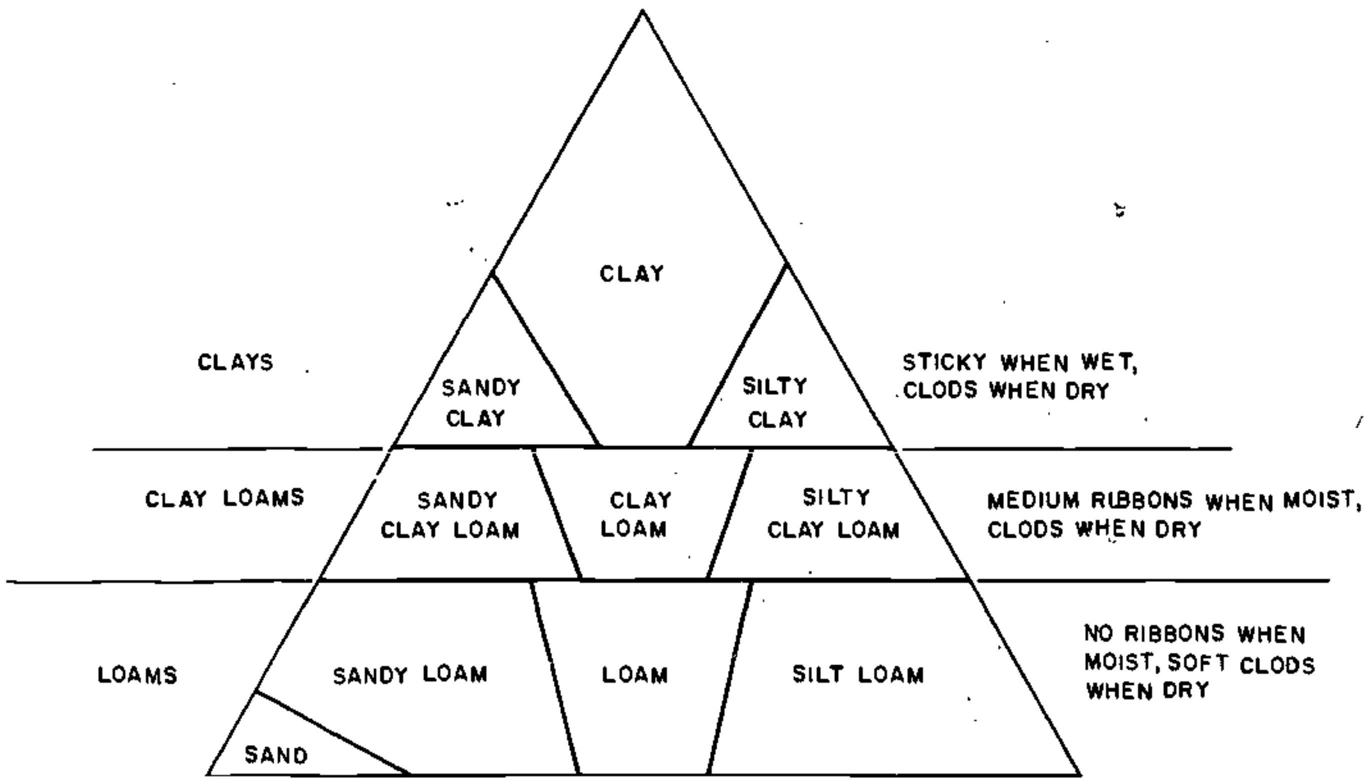
Physical properties of the soil generally mean the size, shape, and arrangements of its particles; the volume and form of its pores; the effective depth of soil from which plants may draw nutrients; and the mineral composition. The flow and storage of water, the movement of air, and the ability of the soil to supply nutrients to plants are determined by its physical properties. These properties differ greatly between the large and small particles. The large size particles are stones, gravels, and sand, and the smaller size particles are called silt and clay. The individual particles of gravel, sand, silt, and clay occupy about one-half of the total volume in a soil. The voids between the particles are called pore space and is occupied by water and soil air. The following are the



Texture triangle showing the percentages of sand, silt and clay in the textural classes. The intersection of the dotted lines shows that a soil with 55 percent clay, 32 percent silt and 13 percent sand has a clay texture.

Figure 1

14



Modified textural triangle for determining soil texture by the feel method.

Figure 2

physical properties of soil which are considered in soil management: (1) texture, (2) color, (3) depth, (4) structure, (5) permeability, (6) moisture-holding capacity, (7) surface drainage, (8) slope.

1. Soil Texture. Soil texture relates to the relative proportions of sand, silt, and clay that are present in the soil. A large amount of sand in a soil will make it coarse and gritty. Such soil may be called sand or sandy loam. It is generally referred to as light soil because it is easier to till. If silt is present in large quantities, the soil feels like flour, is medium in texture, and may be called silt loam or loam. Conversely, a large amount of clay in the soil makes it sticky when wet and hard when dry. Such soil is termed a heavy soil and may be classified as clay or clay loam. Generally, the medium textured soils are considered the best in respect to moisture holding capacity and ease of tillage. Sandy soils are usually well drained, well aerated, and of low water holding capacity. In nature, sand, silt, and clay are almost always mixed together in a great variety of combinations which give the soil its characteristic texture. Physically, the inorganic portion of the soil, called soil separates, is divided into fractions called sand (2.00 - 0.05 mm), silt (0.05 - 0.002 mm), and clay (less than 0.002 mm).

TABLE 1

DIAMETER AND CHARACTERISTICS OF SOIL

Soil Separate	Diameter of particles	General Characteristics
Sand	2-.05 mm	Individual particles feel gritty when the soil is rubbed between the fingers. Not plastic or sticky when moist.
Silt	.05 - .002 mm	Feels smooth and powdery when rubbed between the fingers. Not plastic or sticky when moist.
Clay	less than .002 mm	Feels smooth, sticky and plastic when moist. Forms very hard clods when dry. Particles may remain suspended in water for a very long period of time.

2. Color. Soil color is one of the most noticeable soil characteristics and is widely used to distinguish one soil from another. Yet soil color has relatively little meaning in itself. The color of the top soil is sometimes an indication of soil drainage. Well drained soils generally have a uniform brown color when moist but, in some cases, there may be various shades of red or yellow resulting from the presence of iron or aluminum oxides. A pale or gray color denotes poor drainage. A black surface usually indicates that the land is either rich in organic matter or has remained wet for long periods. This is not a sure formula as parent material also enters into the color of soil.

3. Soil Depth. Soil depth is important to plant growth because it is related to the storage of water, plant nutrients and root extension. The depth of a soil can be observed in roadcuts, stream banks, or by digging pits. The section or face of the exposure made by a cut is called a soil profile and may exhibit a succession of separate layers. Although these layers may or may not be separated by sharp lines of demarcation, the upper portion usually contains more humus and is darker in color. This is called the "A" horizon. Usually a finer textured soil body containing little or no organic matter lies below. This may be several feet in thickness, and is called the "B" horizon. As the weathered soil material of the "B" horizon merges with the original parent material the area known as the "C" horizon is encountered. The effective depth of the soil is determined by the depth of soil readily penetrated by plant roots. In a deep soil, plants withstand drought better because the roots are spread through a larger volume of soil. Also, minerals stored in the subsoil are used by plants if roots can reach them. Soils are sometimes classified as very deep soils - over 48 inches in depth; deep soils - 36 to 48 inches; moderately deep - 24 to 36 inches; shallow - 12 to 14 inches; and very shallow - less than 12 inches.

4. Structure. Structure is perhaps one of the most important physical characteristics of soil, yet it is probably the least understood. Sand, silt, and clay seldom occur as separate units in the soil, but combine into small aggregates. These aggregates are structured into prisms, columns, blocks, plates, or granulars. The most common aggregates found in soils are clods, which are more specifically called blocks. Granular structure is most desirable for a seedbed and is the structure which many farmers attempt to develop in the soil by cultivation. The type of structure has a great effect on the permeability of the soil. Top soil structure may be improved by organic matter and cultivation. Soil structure has a direct relationship to soil productivity, soil permeability, and root growth.

5. Permeability. Permeability refers to the movement of water and air through a soil. The rate of water intake, water capacity, depth of root penetration, and degree of internal drainage are all related to permeability. Soils which have sandy or gravelly subsoils have rapid permeability. Subsoils which contain ample amounts of sand and silt have moderate permeability. If subsoils have large amounts of clay and silt they are slowly permeable.

6. Moisture-holding Capacity. This refers to the amount of water that can be stored by a soil for use by plants. In general, the coarser the soil, the lower is the moisture-holding capacity. Conversely, the finer the soil the higher the moisture-holding capacity. Sandy soils are coarse and have a much lower water holding capacity than do clay soils.

7. Surface Drainage. This refers to the relative rate for drainage (removal) of excess water from a soil surface. If water is removed so slowly that the soil remains wet for a long period of time, then the surface drainage is poor. Sometimes surface water may be removed in excessive amounts causing drought conditions.

8. Slope. Slope is measured in degrees but is expressed as a percentage number for convenience. This percentage number is the difference in elevation from one end of a field to another. For example, a difference in elevation of five feet per 100 feet of field length would mean a five percent slope to the field. Fields can be classified as:

   a. Nearly level - less than one foot rise or fall in each 100 feet,

   b. Very gently sloping - one to three feet rise or fall in each 100 feet,

   c. Gently sloping - three to five feet rise or fall in each 100 feet,

   d. Moderately sloping - five to ten feet rise or fall in each 100 feet,

   e. Strongly sloping - ten to fifteen feet rise or fall in each 100 feet,

   f. Moderately steep to steep - fifteen to twenty-five feet rise or fall in each 100 feet.

F. SOIL REACTION

Soils are neutral, acid, or alkaline in reaction. Their degree of acidity or alkalinity is expressed as pH. The term pH is a symbol and is the chemist's means of expressing active acidity or alkalinity.

Acid soils are found chiefly in areas of heavy rainfall. Under any particular rainfall condition, acid soils are more readily formed from acid igneous rocks such as granites and secondary rocks such as sandstone than from basic igneous rocks such as basalts.

Soil acidity is due partly to the process of plant nutrition, to leaching, and, in part, to the weathering of soils. Muck or peat soils develop acidity largely from organic acids which are formed in the decay of large amounts of organic matter. In the case of mineral soils, soil acidity might be defined simply as a condition of low base saturation.

As a plant functions, and carbon dioxide is given off by the roots, carbonic and other mild organic acids are formed in the soil. These acids yield hydrogen which competes on the exchange complex (primarily the clay particles and soil organic matter) for the bases which, in turn, are taken up by the roots of the plant or leached out of the soil.

The hydrogen ions which cause acidity or characterize acidity compete in the soil with bases such as calcium and magnesium of limestone, potassium and sodium of commonly used fertilizers, and such other bases as manganese, copper, zinc, and iron in lesser amounts.

Soil acidity and soil alkalinity present extremes in the equilibrium of these elements under soil conditions. In high acidity, the effect of the hydrogen ion (H^+) predominates. In high alkalinity, it is the effect of the sodium ion (Na^+) producing hydroxyl ions (OH^-). Both conditions result from a deficiency of calcium ions (Ca^{++}) on the exchange complex. An increase in the amount of calcium on the exchange complex will help overcome such deficiency.

G. SOIL FERTILITY

Soil fertility refers to the nutrient supplying properties of the soil. Plants, like any other living thing, need food to live and grow. If they are well fed they will generally grow vigorously, be somewhat resistant to insects and diseases, and will give a good yield. If they are poorly fed they will grow slowly, become weak or generally susceptible to insects and diseases, and usually produce low yields.

There are sixteen elements, listed below, which are essential for normal plant growth and development. Carbon, hydrogen and oxygen are usually obtained by plants from water and air. The remaining elements are obtained from the soil solution and are referred to as primary plant food elements, secondary plant food elements, or micronutrients (elements plants require in microscopic amounts).

1. Carbon. This comes from carbon dioxide in the air. It functions as an element in cell walls. It is a component of plant sugars, a part of the structure of color, and even an element in the fragrance of plant blossoms.

2. Hydrogen. One of the two elements composing water. This element is essential to the plant with carbon and oxygen. It is used in the plant cell in the manufacture of simple sugars and starches.

3. Oxygen. One atom of this element, combined with two atoms of hydrogen, forms water. Oxygen also combines with other elements to form oxides and complex organic compounds.

Primary plant food elements:

4. Nitrogen. Nitrogen is the essential element for building plant materials in the cell. It promotes rapid vegetative growth and gives plants a healthy green color. It improves the quality of leaf crops and tends to increase the protein content of all crops. Nitrogen deficiency may be observed by pale, yellow coloring, stunted growth, and the "firing" of tips and margins of leaves. Nitrogen deficiency also shows up in low protein content.

5. Phosphorous. Phosphorus is essential to all plant growth and is an active ingredient of protoplasm. It stimulates early growth and root formations, hastens maturity, promotes seed production, gives stability to the stem, and contributes to the general hardiness of plants. Phosphate deficiency is characterized by small growth especially in the root development, a spindly stock, delayed maturity, and a purplish discoloration on the foliage of some plants. Poor fruit and seed development are general characteristics.

6. Potassium. Not too much is known about the function of potassium in the plants. More is known about what happens when potassium is deficient. It is generally agreed that potassium enhances a plant's resistance to disease, tolerance of cold, and other adverse

conditions. Potassium deficiency usually results in a slow growing plant. The margins of the leaves develop a scorched effect, starting first with the older leaves. The plants lodge easily, the fruit or seed is somewhat shriveled, and the plants seem to have low resistance to rust and other diseases.

Secondary plant food elements:

7. Calcium. Calcium is believed to help in the translocation of carbohydrates in the plant. It is considered essential to healthy cell walls and aids in the development of root structure. Calcium is the active element in liming materials used to correct soil acidity. It also occurs in gypsum which is used in the treatment of saline and alkali soils. Calcium deficiency is generally characterized by the terminal bud or growing point of the plant dying under severe deficiency and the margins of affected leaves have a scarlet appearance. The foliage not so affected is usually abnormally dark green. The plant has a tendency to shed its blossoms and buds prematurely and sometimes the stem structure is weakened.

8. Magnesium. Magnesium is an essential ingredient of chlorophyll and aids in the translocation of starch within the plant. It is also essential for the formation of oils and fats and aids in the translocation and absorption of phosphorous in plants. Magnesium deficiency is generally indicated by leaves losing their color at the tips and between the veins, starting with the lower leaves and proceeding upward, depending upon the degree of deficiency. The leaves are abnormally thin. Leaves of plants are brittle and have a tendency to curve upward.

9. Sulphur. Sulphur is associated with plant protein. It also aids in the synthesis of oils. Sulphur deficiency is characterized by the lower leaves turning yellowish-green. Stems are small in diameter and hard and woody. Although root growth is sometimes well developed and extensive, the roots are small in diameter.

Micronutrient elements:

10. Boron. Boron is associated with calcium utilization within the plant. Whenever the proportion of calcium to boron becomes unbalanced because of a deficiency of boron, the terminal part of the plant fails to develop properly. The amount of boron required by plants is extremely small; however, even a slight increase over the required amounts will sometimes bring severe

toxicity. Symptoms of boron deficiency usually show marked changes in the tip of the growing point of the plant, sometimes being tinged with reddish brown areas. The terminal bud becomes light green in color. In root crops, boron deficiency results in a brown heart characterized by dark spots on the thickest part of the root, or splitting at the center.

11. Copper. Copper is an activator or catalyst of other reactions within the plant. It seems to promote the formation of Vitamin A and appears to have a regulating function if soil nitrogen is too high. An excess of copper is very toxic. Copper deficiency symptoms result in foliage with a chlorotic condition which gives a bleached appearance. Citrus fruits show a die-back of new growth. In citrus fruits, also, the trees are marked with a reddish-brown secretion.

12. Iron. Iron is essential for the formation of chlorophyll. Iron apparently enters into the oxidation processes which release energy from sugars and starches. Iron deficiency symptoms show chlorosis of leaves - the youngest leaves being affected first, then the points and margins of leaves are affected while the veins remain green. The affected leaf is sometimes curved in an upward direction.

13. Manganese. Manganese is closely associated with copper and zinc and also acts as a catalyst in plant growth processes. Manganese deficiency symptoms result in a chlorosis between the veins of the young leaves. Even the smallest branches of the veins remain green while the tissue between the veins is light-green, yellowish or almost white. Loss of color is often followed by development of spots of dead tissue which may even drop out giving the leaf a ragged appearance. Sometimes the entire plant is considerably dwarfed.

14. Molybdenum. Molybdenum is associated with nitrogen utilization. Very small amounts are needed. Plants containing an excess of this element are sometimes toxic to livestock. Deficiency symptoms show plants stunted and yellow in color closely resembling nitrogen deficiency plants.

15. Zinc. Zinc is apparently linked with iron and manganese in the formation of chlorophyll. Deficiency symptoms usually show terminal leaves abnormally small - a condition known as "little leaf" in fruit trees. Fruit bud formation is severely reduced. Some plants have mottled leaves and dead areas.

16. Chlorine. Chlorine is the latest element established as essential for plant growth. In plant life, it is believed to stimulate the activity of some enzymes, to influence carbohydrate metabolism or the production of chlorophyll, and the water-holding capacity of plant tissue. Generally, there is no deficiency of chlorine in the soils except in the humid regions. Normal rainfalls supply sufficient chlorine to maintain a normal supply in the soils.

We speak of plant food elements removed from the soil by crops. The three elements - nitrogen, phosphorous, and potassium, which we have termed primary elements, are also called the fertilizer elements and are indicated by the symbols N, P, and K. Thus a fertilizer is termed a complete fertilizer when it has the three elements (N, P, and K) in its formula. These three elements are all needed by plants in substantial quantities. Each must be furnished to the plant from supplies in the soil, or added to the soil by manures or chemical fertilizers. The so-called micronutrients are needed by plants in comparatively small amounts and are usually present in soils in quantities sufficient to meet the needs of the plant. It is generally the quantities of N, P, and K in the soil which determine its fertility.

Various crops differ in their nutrient needs. One crop may require more nitrogen while another may require more phosphate. Generally speaking, the higher the yield of a crop, the greater the demand for all the necessary elements.

H. APPLICATION OF FERTILIZERS

As a general rule, the best time to apply fertilizer to any crop is before the main growth has started. This, of course, will depend on a number of factors such as the type of crop, soil, weather, and moisture conditions. It is often the practice to apply a phosphate fertilizer to fall sown grains at seeding time and top-dress with a nitrogenous fertilizer early the following spring. Corn is often fertilized at seeding time and given an additional amount of nitrogen fertilizer when the crop is well established. Other intertilled crops are given similar side dressings of fertilizers as the crop or excessive leaching demands.

Fertilizers are usually applied in one of several ways. They are either broadcast over the entire soil surface, placed in the hill or row close to the seed or root, or incorporated into the soil during plowing or cultivation.

Top-dressing, or broadcast fertilization, is widely used in orchards, pastures, and for general grain and legume crops. Penetration of the nutrients into the root zone is accomplished by rainfall and irrigation water or by injecting an anhydrous or aqua solution into the soil. Another method of top-dressing is the application of liquid or soluble dry fertilizer materials into the irrigation water.

Direct contact of seed with nitrogen and potassium fertilizer in the soil may have a detrimental effect on the germination of the seed. Grain drills with fertilizer distributing attachments are preferred to mixing the fertilizer with the seed even though small grains can tolerate some contact. Placement machinery has been developed which will place the fertilizer an inch or two below the seed.

Placing the fertilizer under the soil surface in a strip or band to the side and below the seed has proven efficient. Localized applications give more efficient use of smaller amounts of fertilizer and does not readily assist weed growth. Because fertilizer has a tendency to move up and down with only a small amount of lateral movement, placement of fertilizer directly below the seed may be detrimental to seed germination as well as taproot development.

Side dressing is the banding of fertilizers after the plant has emerged. Materials are usually banded along the side of the bed or hill below the water line along the irrigation furrow. Good control of this placement puts the plant food within easy reach of the feeding roots during the growth period when the need is great.

When applying fertilizer in conjunction with irrigation water, accuracy in measurement of the water as well as the fertilizer material is important for efficiency.

I. SOIL ORGANISMS

Raw organic matter in the soil is not directly useful to the plants. It must first be broken down into humus and then into simpler organic products before it can be utilized. Decomposition of organic matter primarily forms part of the feeding and growth processes of billions of different micro-organisms. Sugar, starches, and proteins are broken down first; then cellulose and fatty substances; and lastly lignin or woody substances.

Not all soil organisms are beneficial. There are certain bacteria which release nitrogen to the air where it is lost for plant use. Some others cause plant diseases. Soil micro-organisms have been classified as:

Microflora: Bacteria, Actinomycetes, Fungi and Algae

Microfauna: Protozoa and Nematodes

Besides these, the soil also harbors a large number of worms and insects of different kinds and sizes.

The soil organisms vary in numbers from a few per acre to many millions per gram of soil. The density of organic population is determined by food supply, moisture, temperature, physical condition and chemical reaction. In more or less neutral soils, bacteria dominates the microscopic life. If the soil is acid and rich in organic matter, fungi predominate. Algae abound near the surface in constantly moist and shady localities.

One of the most important types of bacteria is collectively known as nitrifying bacteria. These bacteria attack the complex organic material, and change the nitrogen compounds to ammonia, the ammonia to nitrites, and the nitrites into nitrates. Though found in most cultivated soils, the nitrifying bacteria are generally confined to the top ten to twelve inches. They work best at temperatures between 25 and 38° C, and under conditions of thorough tillage, good aeration, and soil moisture content of approximately 60% of the total moisture holding capacity.

Two other groups of bacteria take up free nitrogen from the air and convert it into nitrogenous compounds for the use of plants. One group functions symbiotically with leguminous plants while the other fixes free nitrogen independently of the legumes. The amount of nitrogen added to the soil by these bacteria varies from 50 to 150 pounds per acre.

Most of the soils are inhabited by worms, insects, and other animals of different sizes. It has been estimated that the earthworms in an acre of soil will pass fifteen tons of soil through their bodies leaving castes weighing 16,000 pounds per acre. Earthworms help form favorable soil structure and improve the nutrient status of soils.

Insects and some other larger animals assist aeration and water percolation. They make channels and burrows in the soil for protection or in quest of food.

J. SOIL CONSERVATION

Soil and its related productivity is our greatest natural resource. Once lost, it can never be replaced. Yet, year after year, tons of rich topsoil are lost through carelessness and poor farming methods. This loss is brought about by either wind or water.

Water erosion is generally classified into three types: gully, rill, and sheet erosion. In gully erosion, soil losses are generally of such a nature that channels large enough to interfere with mechanical cultivation are formed. Rills are thought of as small gullies not large enough to interfere with mechanical operations. Sheet erosion is not easily observed, but often causes more damage than gully or rill erosion. It removes a thin covering more or less uniformly during every rain producing a runoff.

Each year erosion costs American farmers several millions of dollars through reduced productivity of the land. Floods devastate large areas of city and farm land. Accidents in which farm tractors roll over into gullies annually cause several deaths.

Soil erosion by water action is influenced greatly by precipitation, percent slope, length of slope, type of soil, and the nature of the ground cover.

Rainfall is the most important factor influencing soil erosion. Intensity, duration and frequency influence the rate and volume of runoff. As intensity of rain increases and the soil becomes saturated, soil loss results from the runoff. Rainfall of long duration and greater frequency increases both the total runoff and soil loss.

The speed and extent of runoff increases as the slope of the land increases. Therefore, soil loss increases rapidly as the slope of the field becomes steeper.

The type of soil, i.e., its structure, texture, organic matter content, infiltration capacity and permeability greatly affect soil loss and runoff. Soil left in a loose and pulverized condition is particularly liable to erosion through sheet wash and gullying.

When rain falls on a surface covered by a thick mantle of plants, its velocity and erosive powers are reduced. Most of the water either quickly percolates into the soil or moves over the surface with non-erosive velocity. Areas not so protected are unable to absorb the water as effectively. The dashing rain shatters the soil surface. The fine soil particles go into solution or suspension and the thick mixture of water and soil quickly fills and closes the pores in the soil. Infiltration is drastically reduced while runoff and soil loss is increased.

Effective methods have been developed to minimize soil erosion and are being employed on thousands of farms. The basic factor in the application of soil conserving practices is the proper utilization of the land according to its capabilities.

This is largely a matter of crop adaptation and management. Management practices which contribute to the conservation and productivity of agricultural lands form what is known as conservation farming.

One of the most successful methods of controlling runoffs on sloping land is to carry out all cultivation operations and to sow all crops along the contour. Farming on the contour reduces runoff, saves more moisture for crop production, reduces soil losses and increases crop yields.

Incorporation of organic material into the top few inches of the soil has aided in controlling both wind and water erosion.

Strip cropping is the growing of a sod crop in strips of suitable width across slopes, alternating with cultivated crops. This is essentially a form of crop rotation and is important in controlling runoff erosion.

Using grass as stabilizing agents is recommended in many areas. Permanent waterways stabilized with sod aid in removing excess water from the land. Using a grass crop as a part of the rotation assists in holding the soil in place. Areas of severe erosion should be permanently returned to grass.

Mechanical soil conservation measures are adopted to supplement the cultural methods. The design of mechanical structures to control erosion are based on three general principals:

1. Allowing more runoff water to be absorbed and held by the soil.
2. Dividing a long slope into several short ones to maintain a minimum velocity for the runoff water.
3. Protection against damage due to runoff such as basin listing, contour terracing, ponds, etc.

Where erosion is relatively mild, the most effective control is obtained through a combination of crop rotation and striving for maximum yields. Research has shown that if the organic matter content of the soil is high, the rate of erosion is reduced. A crop rotation including perennial forage crops results in better maintenance of organic matter than continuous cropping to row crops. Similarly, when crops are managed in such a way that maximum yields are obtained, the soil is protected in two ways. The increased top growth protects the soil from the beating force of rain or wind and the higher yields result in more crop residues, especially roots, being left in the soil as organic matter.

UNIT II - PLANTS

A. INTRODUCTION

That branch of science which deals with the study of plants is called botany. Plants occupy a very prominent position in our lives. It is the green plants that keep the air we breath supplied with oxygen. Plants supply us with all our primary biological needs. However, they also cause many of the most serious diseases of man. At the same time, they provide many of the medicines used to cure disease. It is by working directly with plants or with plant products that a majority of the world's workers earn a living.

B. CLASSIFICATION OF PLANTS

Plants may be classified in different ways. Many different systems have been used, but the one most generally accepted is based upon the similarity or relationship of plant parts. According to this system, the entire plant kingdom is subdivided into the Thallophyta, Bryophyta, Pteridophyta, and Spermatophyta divisions.

The lowest division, Thallophyta, is characterized by plants that have no roots, stems, or leaves. Many of these plants consist of but a single cell and are relatively simple in structure. Many, like algae, live entirely in water. Others like toadstools and mushrooms grow on dry land or on dead and decaying matter. All bacteria belong to this group, living in the soil on dead and decaying matter or in other living organisms where they sometimes cause disease.

The Bryophyta division is made up of the so-called "moss plants". These plants also lack roots, stems and leaves as we generally think of them. They differ from the Thallophytes primarily in their reproductive system. To this division belong all the common mosses and their relative, the liverworts, both of which are found living in moist places or in water.

The ferns exemplify the third group called the Pteridophytes. These plants differ from the two lower divisions in that they have true roots, stems, and leaves. They also have a well defined conducting system. They differ from the higher plant division in that they do not produce flowers, fruits, and seeds. This group is made up of the ferns and their close relatives, the club mosses, horsetails, and scouring rushes.

The highest division of the plant kingdom, called the Spermatophytes, contains all crop plants as well as all the common trees, shrubs and flowering plants. These plants all have roots, stems, leaves and a highly developed conducting system. The most important feature is that they produce seed.

The Spermatophyta division is divided into two subdivisions; the gymnosperms and the angiosperms. The gymnosperms are characterized by producing their seeds exposed. The term gymnosperm means naked seed. This group is represented in temperate regions by the pine, spruce, cedar and other evergreens. The angiosperms produce their seed enclosed in a fruit. The members of this group are very numerous and embrace all of the well known flowering plants.

The angiosperms are further subdivided into two classes; the monocotyledons and the dicotyledons. The essential differences between these two groups are: (1) The embryo of the monocot contains but a single cotyledon or first leaf while the dicots contain two. (2) The organs of the flowers in the monocots are usually in threes or multiples of three, while in the dicots, they are mainly in fours or fives or multiples of these numbers. The monocots are represented by the grass-like plants, such as corn, wheat, oats and other grasses, and other plants such as the lily, bamboo, and banana. The dicotyledons include the broad-leafed forest plants and many ornamental and crop plants such as beans, peas, clover and buckwheat.

This classification goes several steps further. The classes are divided into Orders. The orders are broken down into families, the families into genera, and the genera into species. Oftentimes, the species are further subdivided into varieties.

The following example illustrates the complete classification of sweet corn.

Kingdom	Plant
Division	Spermatophyta
Subdivision	Angiosperms
Class	Monocotyledons
Order	Graminales
Family	Gramineae
Genus	Zea
Species	Mays
Subspecies	Saccharata
Variety	Golden Bantam

For more practical use, plants are often classified according to their botanical relationships, their use, the cultural treatments imposed, the seasons in which they grow or according to their life-cycle.

Botanical classification

We need to become more specialized in the identification of the more common plant families. Consequently, Figures 3 through 42 provide an illustration and short description of the members of the herbaceous flowering plant families as an aid to their differentiation and identification.

SEDGE FAMILY -
(cyperaceae)
Annual or perennial grass-like herbs with triangular solid stems and 3-ranked leaves; the leaf sheath closed; flowers in spikelets with 2-ranked or spiral scales, with or without basal bristles, or sometimes in a sac-like structure.

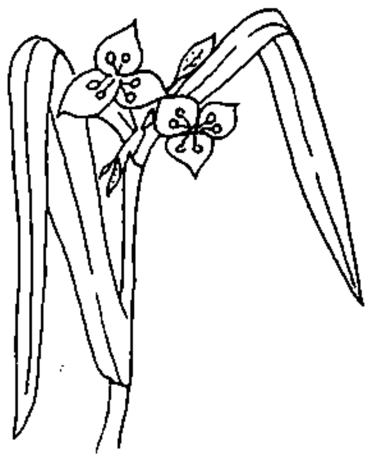
Figure 3 - CYPERUS

GRASS FAMILY -
(gramineae)
Annual or perennial herbs with round, hollow stems and 2-ranked leaves, and a leaf sheath split.

Figure 4 - CRAB-GRASS

RUSH FAMILY -
(juncaceae)
Mostly perennial, grass-like, usually tufted herbs; papery and glume-like.

Figure 5 - RUSH



SPIDERWORT FAMILY -
(commelinaceae)
Mostly perennial more or less lily-like plants with a short inflated leaf sheath; sepals 3 green, petals 3, usually blue, wither very rapidly.

Figure 6 - SPIDERWORT

NETTLE FAMILY -
(urticaceae)
Mostly tall herbs with opposite stipulate leaves, sepals 4; corolla none; stamen 4; fruit an achene. Flowers are greenish.

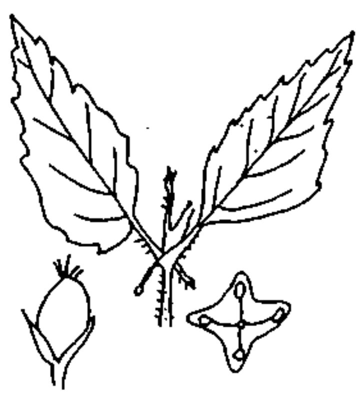


Figure 7 - TALL NETTLE

LILY FAMILY -
(liliaceae)

Perennial herbs or a few woody vines, mostly with bulbs, corms, or rootstocks; inflorescence various; sepals 3, usually like the petals; petals 3; and perianth parts separate or united.

(A) WESTERN LILY (B) STAR-OF-BETHLEHEM (C) WILD GARLIC
(D) SMOOTH SOLOMON'S SEAL (E) ROUNDLEAF GREENBRIER

Figure 8

BUCKWHEAT FAMILY -
(polygonaceae)
Herbs with alternate leaves and sheathing stipules; corolla none; sepals 4-6, greenish or pinkish.

Figure 9 - DOCK

GOOSEFOOT FAMILY -
(chenopodiaceae)
Annual herbs with alternate, mostly mealy coated leaves, without stipules; flowers small, greenish, in tight groups; sepals usually 5.

Figure 10 - LAMB'S QUARTERS

AMARANTH FAMILY -
(amaranthaceae)
Coarse annual herbs with alternate leaves without stipules; flowers bracted; sepals usually 5; stamen usually 5; and style 2 or 3.

Figure 11 - ROUGH PIGWEED

PURSLANE FAMILY -
(portulacaceae)
Annual or perennial fleshy-leaved herbs without stipules; our common weed prostrate; flowers small, terminal; sepals 2; petals 5; and stamen 8 or more.

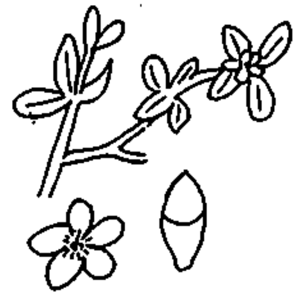


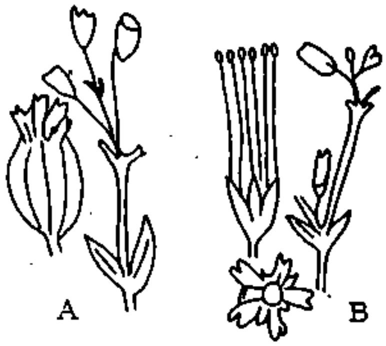
Figure 12 - COMMON PURSLANE

CARPET-WEED FAMILY -
(aizoaceae)
Annual prostrate herbs branched at base; leaves narrow, in whorls; flowers small whitish; sepals 5; corolla none; stamen 3 or 5; style 3.

Figure 13 - CARPET-WEED

FOUR-O'CLOCK FAMILY -
(nyctaginaceae)
Medium tall herbs with opposite leaves; flowers above a 5-lobed involucre; corolla none; caylx tubular, petal-like, 5-lobed; stamen 3-5; style 1.

Figure 14 - UMBRELLA-WORT



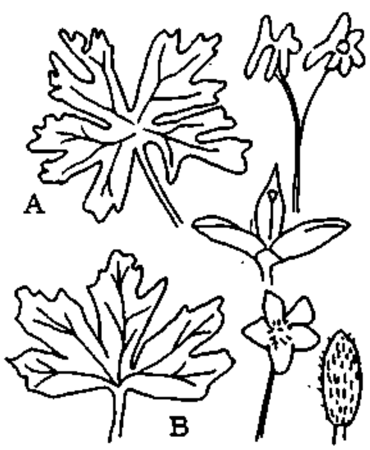
PINK FAMILY -
(caryophyllaceae)
Annual or perennial herbs with opposite leaves and short or no petioles; flowers white, pink or red; petals 5, mostly notched at apex; sepals mostly 5, often united; stamen usually 10; style 2-5; often toothed at top when open.

Figure 15 - (A) CATCHFLY (B) CHICKWEED

GERANIUM FAMILY -
(geraniaceae)
Herbs with 3-5 parted leaves;* sepals 5; petals 5; stamen usually 10; style united to form a beak; ovary 5-lobed and 5-celled; fruit a 5-celled capsule; each cell 1- or 2-seeded.

*opposite or alternate

Figure 16



CROWFOOT FAMILY -
(ranunculaceae)
Annual or perennial herbs with alternate mostly compound or lobed leaves and no stipules; flowers mostly showy, regular, or irregular and spurred; sepals 3-15, often petal-like; petals same number as sepals or none; stamen many; carpels few to many, great variation, pistils not united; flower parts on receptacle.

Figure 17 - (A) LARKSPUR (B) ANEMONE

MUSTARD FAMILY -
(cruciferae)

Mostly annual or biennial herbs with alternate, entire or variously lobed leaves; flowers mostly white or yellow; sepals 4; petals 4; stamen 6 with inner 4 longer.

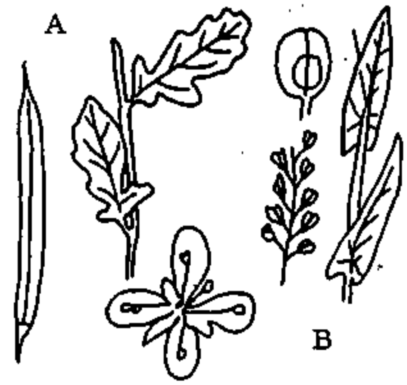
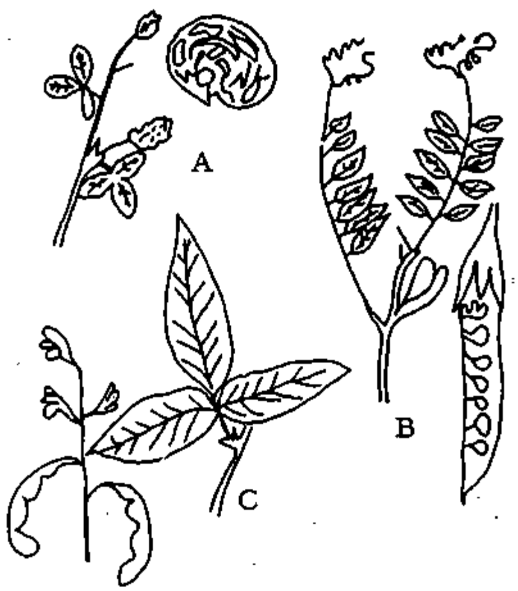


Figure 18 - (A) MUSTARD (B) FIELD PEPPERGRASS



PEA FAMILY -
(leguminosae)

Herbs, herbaceous vines, shrubs or trees with alternate, mostly compound leaves with stipules; flowers irregular and mostly bean-like; caylx 4-5 toothed, petals 5 usually more or less united; stamen mostly 10, united in 1 or 2 sets, jointed between the seeds in 1 tribe.

Figure 19 - (A) BLACK MEDIC (B) VETCH (C) TICK CLOVER

ROSE FAMILY -
(rosaceae)

Mostly perennial herbs, shrubs or trees, most with compound leaves and conspicuous stipules; flowers mostly showy, white, yellow or pink; sepals 5; petals 5; stamen numerous; carpels 1-many.

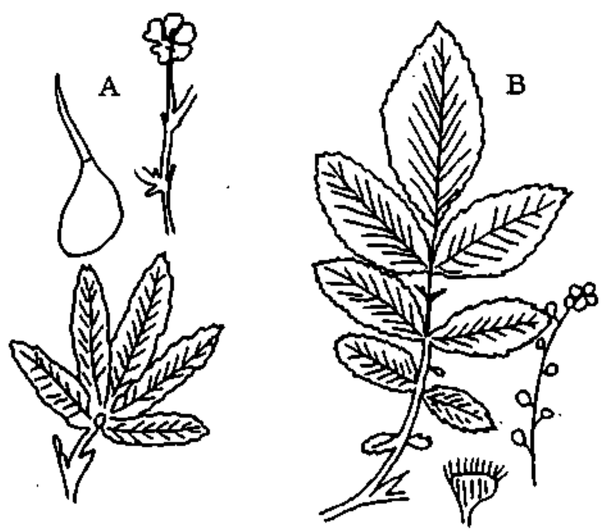


Figure 20 - (A) ROUGH CINQUEFOIL (B) AGRIMONY

WOOD SORREL FAMILY -
(oxalidaceae)
Annual or perennial low herbs with sour sap and clover-like leaves; sepals 5; petals 5; yellow or pink; stamen 10-15; style 5 or united; 2-several seeds in each cell.

Figure 21 - YELLOW WOOD SORREL

CARROT FAMILY -
(umbelliferae)
Herbs with alternate, mostly compound leaves; flowers in umbels, mostly white or yellow, small, caylx 5-toothed, adnate to ovary; petals 5; stamen 5.

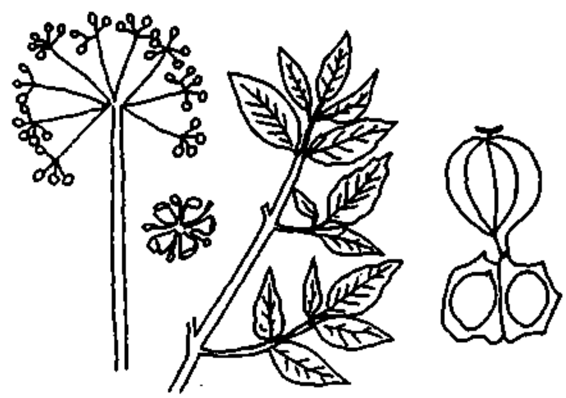


Figure 22 - WATER HEMLOCK

MALLOW FAMILY -
(malvaceae)
Herbs or shrubs with alternate leaves; sepals 5, somewhat united; petals 5, stamen many, united in a tube around style; style united except at apex.

Figure 23 - ROUNDLEAF MALLOW

SPURGE FAMILY -
(euphorbiaceae)
Herbs with alternate, opposite or whorled leaves; flowers mostly small; sepals 5-6 or none; petals 5-6 or none; involucre calyx-like in some; stamen few-numerous; style mostly 3; plants with milky juice.

Figure 24 - SPURGE

EVENING PRIMROSE FAMILY-
(onagraceae)
Annual or perennial herbs with opposite or alternate leaves; calyx tubular, mostly 4-lobed; petals usually 4; style united except at apex; fruit a many-seeded capsule; stamen 4 or 8.

Figure 25 - COMMON EVENING PRIMROSE

BORAGE FAMILY -
(boraginaceae)
Herbs, mostly rough hairy, flowers rather small, white, yellow or purple; calyx 5-lobed or parted; corolla tubular, 5-lobed at apex; stamen 5 on the corolla tube; style simple or 2-divided; nutlets often bur-like.

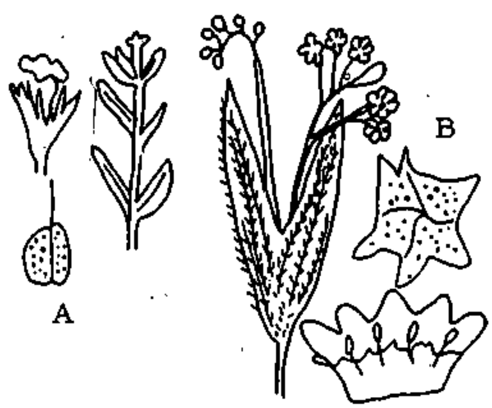
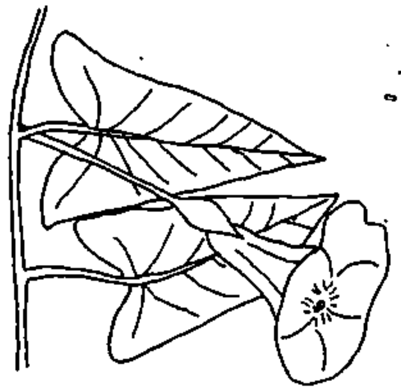


Figure 26 - (A) CORN CROMWELL (B) HOUND'S TONGUE



MORNING-GLORY FAMILY -
(convolvulaceae)
Mostly twining herbs with alternate leaves; flowers usually large; calyx 5-parted; corolla tubular, 5-lobed; stamen 5, low on the corolla tube; style entire to the stigma or 2-divided.

Figure 27 - HEDGE BINDWEED

DOGBANE FAMILY -
(apocynaceae)
Perennial herbs or vines, flowers mostly small, whitish or pinkish; calyx 5-parted; corolla tubular, 5-lobed or parted at apex; stamen 5, short, on the corolla; style simple or 2-divided; plants mostly with milky juice.

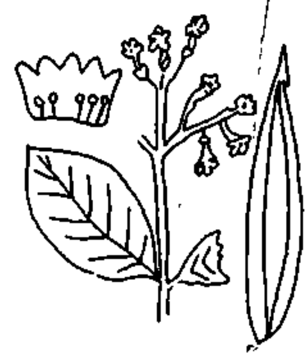
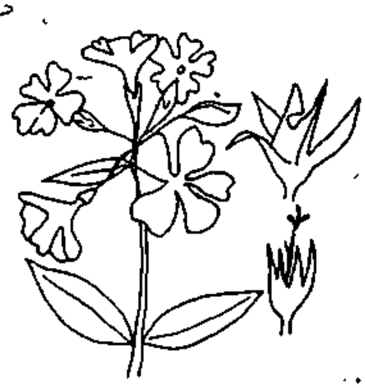


Figure 28 - INDIAN HEMP



PHLOX FAMILY -
(polemoniaceae)
Herbs with mostly opposite leaves; flowers mostly conspicuous; blue, white or pink; calyx 5-parted; corolla tubular, 5-parted at the apex; stamen 5 on the corolla tube; style long, 3 divided at apex; mostly many seeded.

Figure 29 - PHLOX

WATERLEAF FAMILY -
(hydrophyllaceae)
Herbs, mostly conspicuously with alternate or basal, lobed or divided leaves; flowers conspicuous, white, blue or purple; calyx 5-parted; corolla mostly short tubular, 5-parted at apex; stamen 5 on the corolla tube, often conspicuously exceeding the corolla; style 2 or 2-divided.

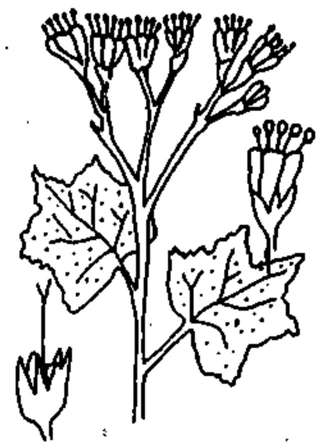
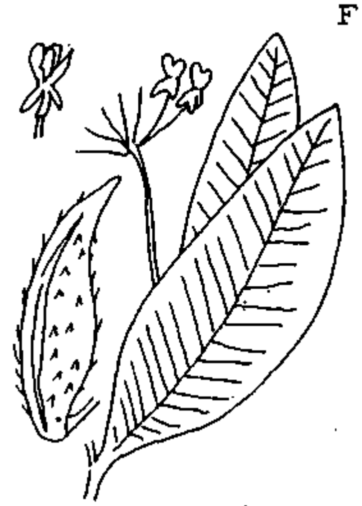


Figure 30 - WATERLEAF



MILKWEED FAMILY -
(asclepiadaceae)
Perennial herbs or vines with alternate, opposite or whorled leaves; flowers mostly in umbels, small; calyx short, 5-parted; corolla 5-parted, mostly reflexed; stamen 5, united around the stigma; style 2, joined to form a disk-like stigma; plants with milky juice.

Figure 31 - MILKWEED

DODDER FAMILY -
(cuscutaceae)
Twining, yellow or white parasites on green plants; flowers small; calyx 5-lobed or parted; corolla 5-lobed, stamen 5, on the corolla tube; style 2.

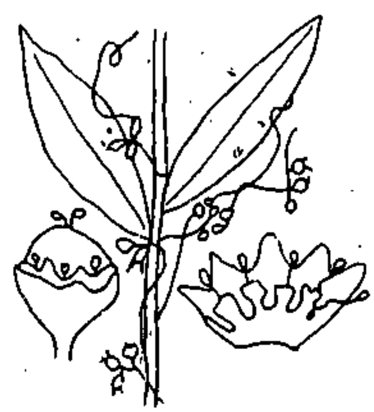
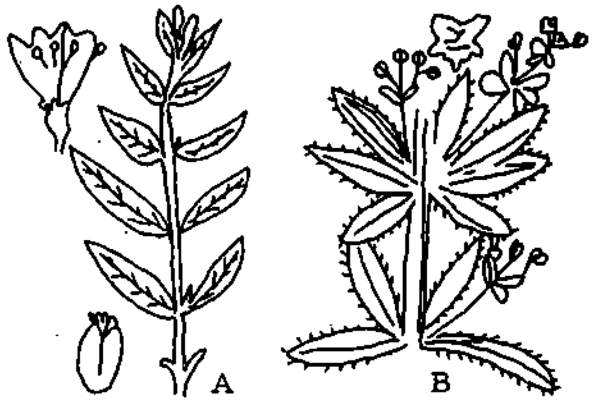


Figure 32

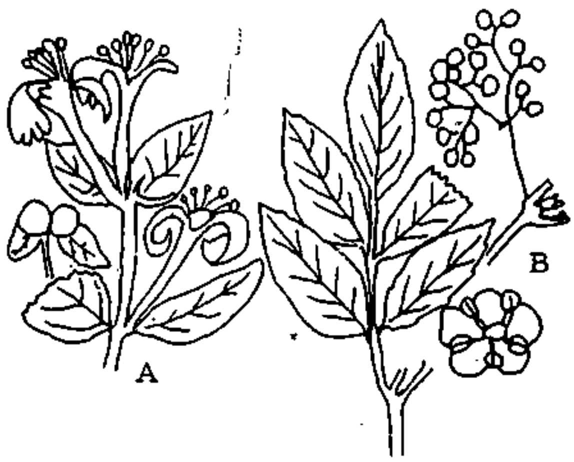


MADDER FAMILY -
(rubiaceae)
Mostly low herbs with opposite or whorled leaves; calyx tubular, 4-lobed; corolla tubular, 4-lobed; stamen 4 on corolla tube.

Figure 33 - (A) BUTTONWEED (B) CLEAVERS

MINT FAMILY -
(labiatae)
Herbs, mostly aromatic - punctuate, with opposite leaves; flowers mostly small, irregular, mostly in axillary or terminal groups; calyx 5-lobed or toothed; corolla 2-lipped, the lower lip 3-lobed; the upper 1- or 2-lobed. tubular; stamen 4, rarely 2, usually 2 long and 2 short, on the corolla tube; style 1; plants with square stems.

Figure 34 - (A) WILD BERGAMOT (B) MOTHERWORT

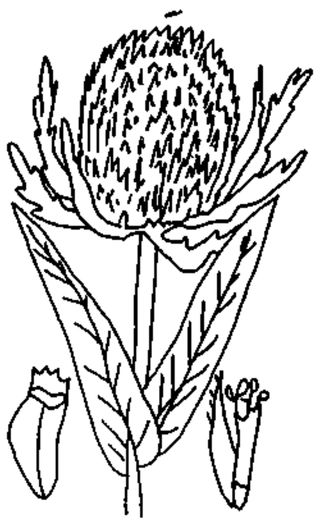


HONEYSUCKLE FAMILY -
(caprifoliaceae)
Mostly shrubs and vines with opposite leaves; calyx tubular, 3-5 lobed; corolla tubular, 5-lobed, sometimes 2-lipped; stamen 5 on corolla tube; mostly berries or drupes.

Figure 35 - (A) JAPANESE HONEYSUCKLE (B) ELDER BERRY

PLANTAIN FAMILY -
(plantaginaceae)
Low herbs with basal leaves; calyx 4-parted; corolla tubular, 4-lobed, papery; stamen mostly 4, on corolla tube; style 1; flowers with bracts.

Figure 36 - PLANTAIN

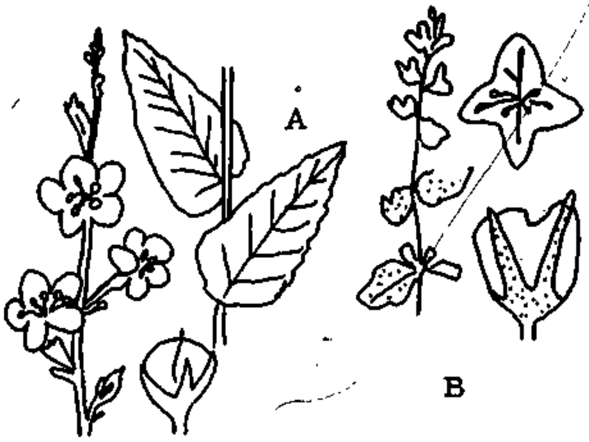


TEASEL FAMILY -
(dipsacaceae)
Tall herbs with opposite leaves; calyx tubular; corolla tubular, 4-lobed; stamen 2-4 on corolla tube; flowers with bracts.

Figure 37 - COMMON TEASEL

VERVAIN FAMILY -
(verbenaceae)
Herbs with opposite leaves, ours mostly hairy; flowers in spikes, bracted, mostly white or purplish blue, small; calyx 4-5 lobed or cleft; corolla tubular, 4-5 lobed at apex, regular or somewhat 2-lipped; stamen 4, 2 long and 2 short, on the corolla tube; 4 nutlets.

Figure 38 - BLUE VERVAIN



FIGWORT FAMILY -
(scrophulariaceae)
Herbs with alternate or opposite leaves; flowers showy or small, mostly snapdragon-like; calyx 4-5 toothed or parted; corolla usually 2-lipped, sometimes nearly regular, tubular, 4-5 lobed or parted at apex; stamen 2, 4, or 5, in 2 sets of unequal length, on the corolla tube; style simple or 2-lobed.

Figure 39 - (A) MOTH MULLEN (B) SPEEDWELL

POTATO FAMILY -
(solanaceae)
Herbs or vines with mostly alternate leaves; flowers regular; calyx 5-lobed or parted; corolla tubular and 5-lobed or 5-parted; stamen 5, on the corolla tube, separate or anthers united around style; many seeded berry.

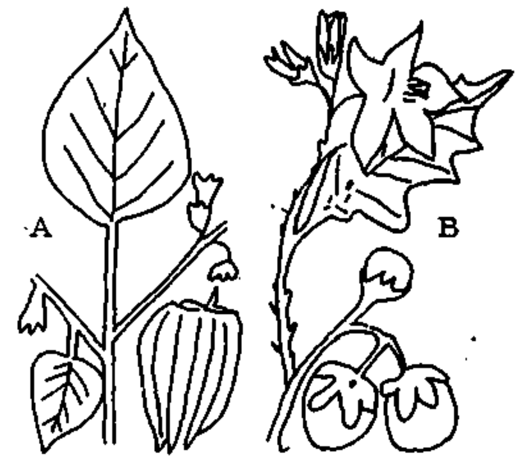


Figure 40 - (A) GROUND CHERRY (B) HORSE NETTLE

COMPOSITE FAMILY 1. (compositae liguliflorae) - Herbs with alternate or basal leaves and milky juice; flowers in involucrate heads, yellow, blue or white; individual flowers small, all alike; calyx completely adnate to the ovary, its free upper portion (limb or pappus) of scales, simple or plumose bristles or wanting; corolla tubular with a 5 notched or toothed petal-like part, (ligule); stamen 5, united in a tube around the pistil; style 1, 2-cleft; ovary 1-celled; 1-seeded; fruit an achene.

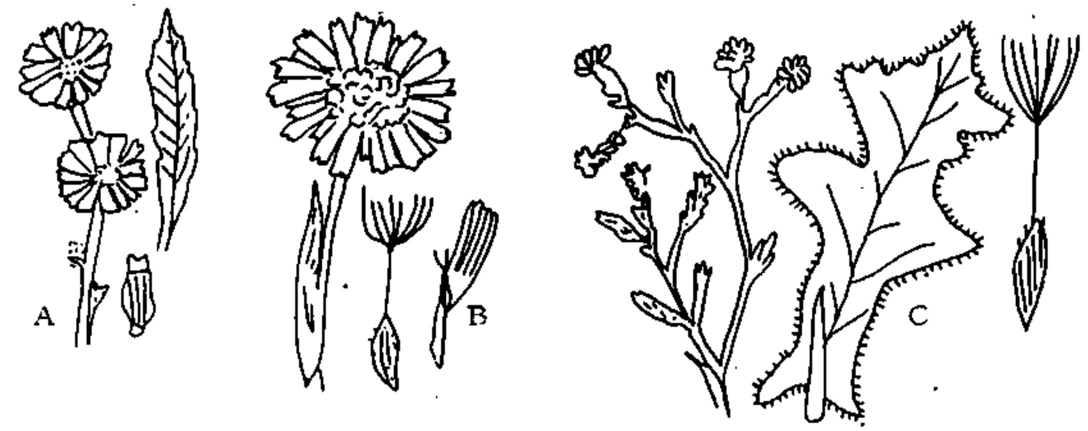


Figure 41 - (A) CHICORY (B) YELLOW GOATSBEARD (C) PRICKLEY LETTUCE

COMPOSITE FAMILY 2. (compositae tubuliflorae) - Herbs with alternate or opposite leaves and flowers in involucrate heads but differing from the above Liguliflorae in having watery juice and ligulate flowers wanting or marginal only (then called ray flowers), the central (disk flowers) tubular only (the corolla not expanded into a ligule) pappus various, stamens around the 2-cleft style, fruit achenes.

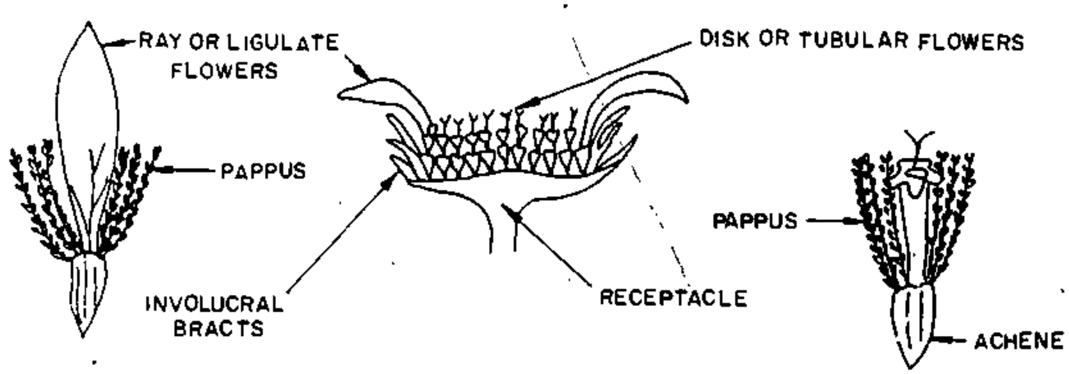


Figure 42 - STRUCTURE OF HEAD OF TUBULIFLORAE

Classification by crops

1. Granineae or Grass Family: wheat, rice, barley, oats, corn, sorghums, sugar cane, millet.

2. Leguminoseae or Pea Family: peas, beans, clovers, soybeans, mungbeans, etc.

3. Liliaceae or Lily Family: onion, garlic.

4. Solonaceae or Potato Family: potato, tomato, tobacco.

5. Malvaceae or Mallon Family: cotton.

6. Compositae or Sunflower Family: sunflower, safflower.

7. Euphorbiaceae or Milkweed Family: castor.

8. Linaceae or Flax Family: flax or linseed.

Classification by general use

1. Cereals: wheat, rice, corn, barley, etc.

2. Pulses: peas, beans, soybeans.

3. Oilseeds: linseed, castor, peanuts, sunflower, soybeans.

4. Fiber: cotton, jute, sisal, kenaf, flax.

5. Stimulant or Drug: tea, coffee, tobacco.

6. Root Crops: potato, sweet potato, sugar beet.

Classification by specific use

On some occasions, plants are used for special purposes. We then place the crop into one of several categories:

1. Silage Crop: Any crop which is cut green and stored for fermentation in an air tight container that is for livestock feed.

2. Soiling Crop: Any crop which is cut green and fed immediately to livestock.

3. Cover Crop: Any crop planted to produce a cover on the land to help reduce soil erosion.

4. Green Manure Crop: A crop, preferably a legume, which is plowed under when green to increase the productivity of the soil.

5. Catch Crop: A short season crop planted so that a little income is realized when the major crop has failed.

6. Nurse Crop: A crop planted frequently to help the establishment of another crop while it is young.

Classification according to life cycle

Plants may also be grouped according to their length of life. Because of this classification, plants are either "annuals", "biennials", or "perennials".

An annual crop is one which completes its life cycle in the course of one year. A biennial crop requires two years to grow, mature, and die, whereas a perennial crop will require more than two years.

Wheat or corn are good examples of an annual crop. Sweet clover and beets are examples of biennial crops as they must live over winter into the second year before being able to flower. Alfalfa is a good example of a perennial crop as it has been grown for periods of twenty to twenty-five years. Sugar cane is normally an annual, but may be grown for two or more years, in which case it becomes a perennial. Cotton may behave as an annual, biennial or perennial depending on the type of cotton and/or the climatic condition under which it is grown.

C. COLORATION IN PLANTS

The most common external characteristics of plants and the most impressive and distinctive is color. Some of the pigments responsible for color are closely tied up with the physiological activities of the plant itself. While it is possible to find all shades and combinations of the colors in the plant kingdom, there is in general a predominance of the primary colors, green, red, blue, and yellow. These colors are imparted to the plant by definite chemical compounds or pigments, each of which has i haracter-istic color. The particular color which a plant organ assume sually caused by the predominance of one or another of these pigments or a combination of several of them. When plants or parts of a plant appear white, it is because of the absence of these pigments.

The green color so uniformly present in plants is caused by a pigment called chlorophyll. This is broken down into two closely related pigments - chlorophyll A and chlorophyll B. Chlorophyll occurs in practically all flowering plants, mosses, ferns, and algae. It will develop in roots, stems, leaves, and fruits, if these organs are above ground and exposed to light. It is not normally present in the flesh of an apple nor is it usually found in underground portions such as roots or tubers. Though not visible, it may be found in red or yellow leaves, when the other coloring matters are extracted. Chlorophyll has been termed the "key to survival" of the plant and animal kingdoms. This green pigment in the chloroplasts receives the light energy from the sun and combines carbon and oxygen from carbon dioxide with hydrogen and oxygen from water to form life-sustaining organic compounds. No other way has been found to unlock nature's elements and combine them into nourishing food.

Just how the plant manufactures chlorophyll has not been determined, but it is well known that certain conditions and substances are necessary for its formation. There must be light of proper intensity. Too much or too little is detrimental. Plants grown in total darkness do not become green. This may be demonstrated by potatoes growing in cellars, or grass growing under boards. A favorable temperature is also necessary for chlorophyll formation; excessive temperatures hot or cold being harmful. In addition, there must be an available supply of oxygen and of salts containing iron, nitrogen and magnesium. A supply of carbohydrates such as sugar is also necessary for chlorophyll formation.

Red is one of the most conspicuous colors found in vegetation. It may be present in leaves, stems, flowers, fruits, and roots. In leaves, it may completely obscure the chlorophyll. Such an example is red cabbage. Most of the red, blue and purple colors in plants are due to a class of chemical compounds known as anthocyanins. These pigments are not contained in plastids, as is chlorophyll, but are found dissolved in the fluid content of the cell and are, therefore, uniformly distributed throughout the cell. In some cases they appear as crystals.

Several yellow pigments collectively known as carotenoids are found in plants, and the most widely distributed of these are carotin and xanthophyll. These two pigments are generally present with chlorophyll in the chloroplasts, often giving healthy green leaves a decidedly yellow tinge. They are not restricted to the chloroplasts alone, but are also found in plastids known as chromoplasts. They are never found dissolved in the cell sap. It is the occurrence of carotin in the roots of the carrot that gives it the bright yellow color. The name of the pigment originated from its presence in the carrot. The yellow color of butterfat and of egg yolks is due to these pigments.

When plant parts appear white, it is because of the absence of pigments. This may be due to a physiological change of the plant or it is sometimes induced by plant nutrient deficiencies and on occasion is present in a diseased plant.

D. HOW PLANTS GROW

The body of a seed plant is made up of distinct parts known as roots, stems, leaves, flowers, fruits, and seeds. The organs are composed of various kinds of tissues, such as storage, conducting, supporting, and protective tissues. Tissues, in turn, are made up of structural and physiological units called cells.

The cell is of great importance because it is the seat of the vital physiological processes and the bearer of the hereditary material from one generation to another. The term cell is applied to the living protoplasm. Protoplasm is generally known as the living material of the whole plant or animal body. It has been referred to as the "physical basis of life". Each typical cell contains a single body called nucellus. The body of the nucellus is composed of what is known as the nucellar gell and chromatin. Chromatin is a very important part because this thickens into bodies called "chromosomes". The inheritances of the plant is determined by materials in these chromosomes.

The growth of plants is a process of a mature cell dividing. The smaller cells grow and enlarge until they become mature, then divide again as growth takes place. The rate of plant growth depends on several factors, among which are the rate at which food materials are supplied, the energy obtained from the oxidation of sugars, the temperature of the area, and the amount of plant nutrients available. As the plant grows and develops, cells unite and perform special functions. Some cells form a conducting tissue which is called phloem. The chief function of phloem is the conduction of foods such as sugars and proteins. Other cells form the generally woody portion, or the xylem portion of the plant. This xylem tissue is generally the water conducting and strengthening tissues of the plant.

The growth process may be said to be the division, enlargement, maturation, and specialization of cells. As these cells grow, divide and specialize, they perform the basic plant functions of photosynthesis, respiration, and transpiration.

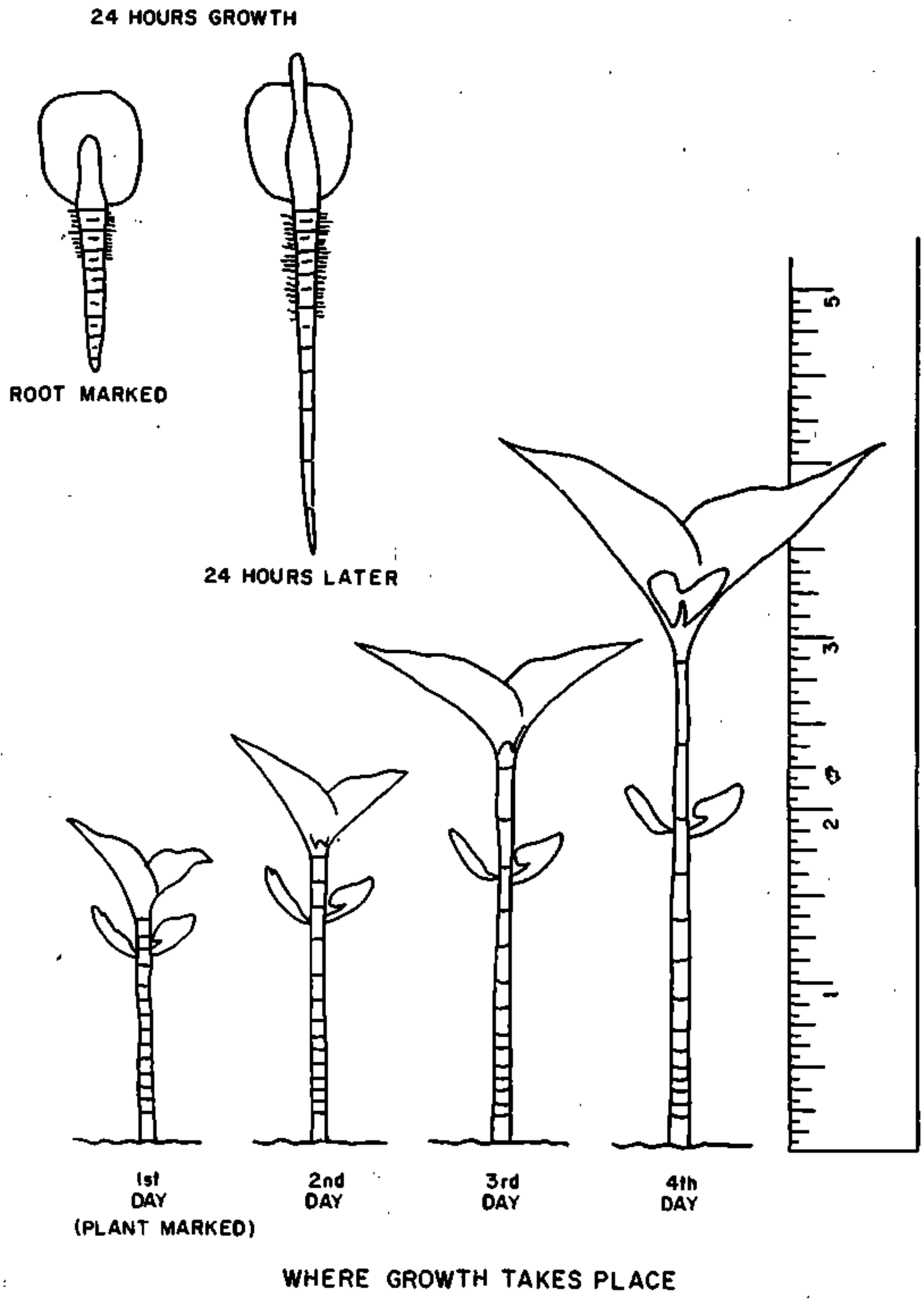

24 HOURS GROWTH
ROOT MARKED
24 HOURS LATER
1st DAY (PLANT MARKED)
2nd DAY
3rd DAY
4th DAY
WHERE GROWTH TAKES PLACE

Figure 43

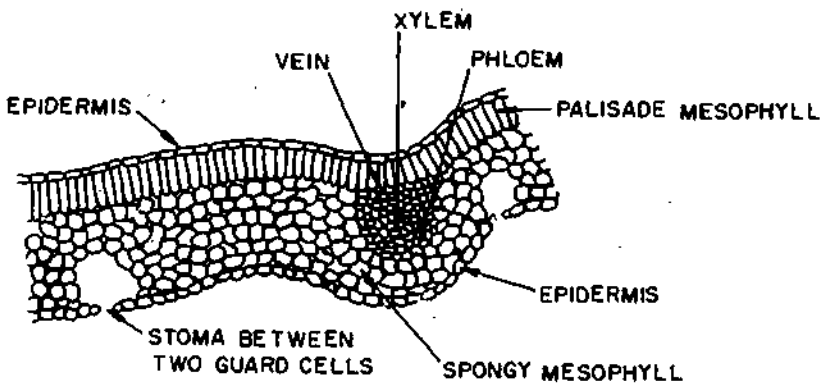
E. LEAVES

Leaves are perhaps the most conspicuous part of plants. Being rich in chlorophyll, they are responsible for the common green color of forests and fields. They are always borne on stems and never on any other organ. The part of the stem to which a leaf is attached is called a node. The upper angle the leaf makes with a stem at its point of attachment is called the axil of the leaf. Invariably a bud is found in this axil although the bud may be so immature as to be invisible to the naked eye.

A complete leaf consists of an expanded portion known as the lamina or blade, a leafstock or petiole by which the blade is attached to the stem, and two small appendages at the base of the petiole called stipules. When any of these parts are lacking, the leaf is said to be incomplete.

The blade of the leaf is strengthened by the presence of veins. These veins are made up chiefly of vascular or conducting tissue which is continuous with that of the petiole. The vein serves to distribute water and dissolved inorganic salts throughout the blade and to carry away foods as they are made.

There are two principal types of venation or veining, parallel venation and net venation. In parallel-veined leaves, the principal veins run parallel to each other from the base to the tip of the leaf. This type of venation is characteristic of the monocotyledonous plants and is especially well defined in the grasses. In net-veined leaves, the veins branch again and again, forming a complete network through the leaf.



CROSS-SECTION OF A POTATO LEAF

Figure 44

The blades of some leaves are deeply indented at the margins. Others are completely separated into individual parts called leaflets. As long as the blade is in one piece, even though deeply lobed, the leaf is said to be simple. When the blade is completely dissected into leaflets, the leaf is said to be compound.

The outermost layer of cells, which extends all over the surface of the leaf, is called the epidermis. The interior of the leaf, between the upper epidermis and the lower epidermis, is called the mesophyll. The lower epidermis, and sometimes the upper, is perforated by numerous pores known as stomata or the singular verb, stoma. Each stoma is a minute opening between two highly specialized epidermal cells called guard cells.

The leaf is the center of two very important processes called photosynthesis and transpiration. Photosynthesis may be defined as the process by which green plants manufacture carbohydrates by putting together carbon dioxide, water, and sunlight. A simplified diagram of photosynthesis is shown in Figure 45. Probably no other plant process has been more thoroughly studied. Yet, in spite of all the investigation, the exact nature of the process is still unknown. The well known facts about the process may be summarized as follows:

1. Water and carbon dioxide are the raw materials.

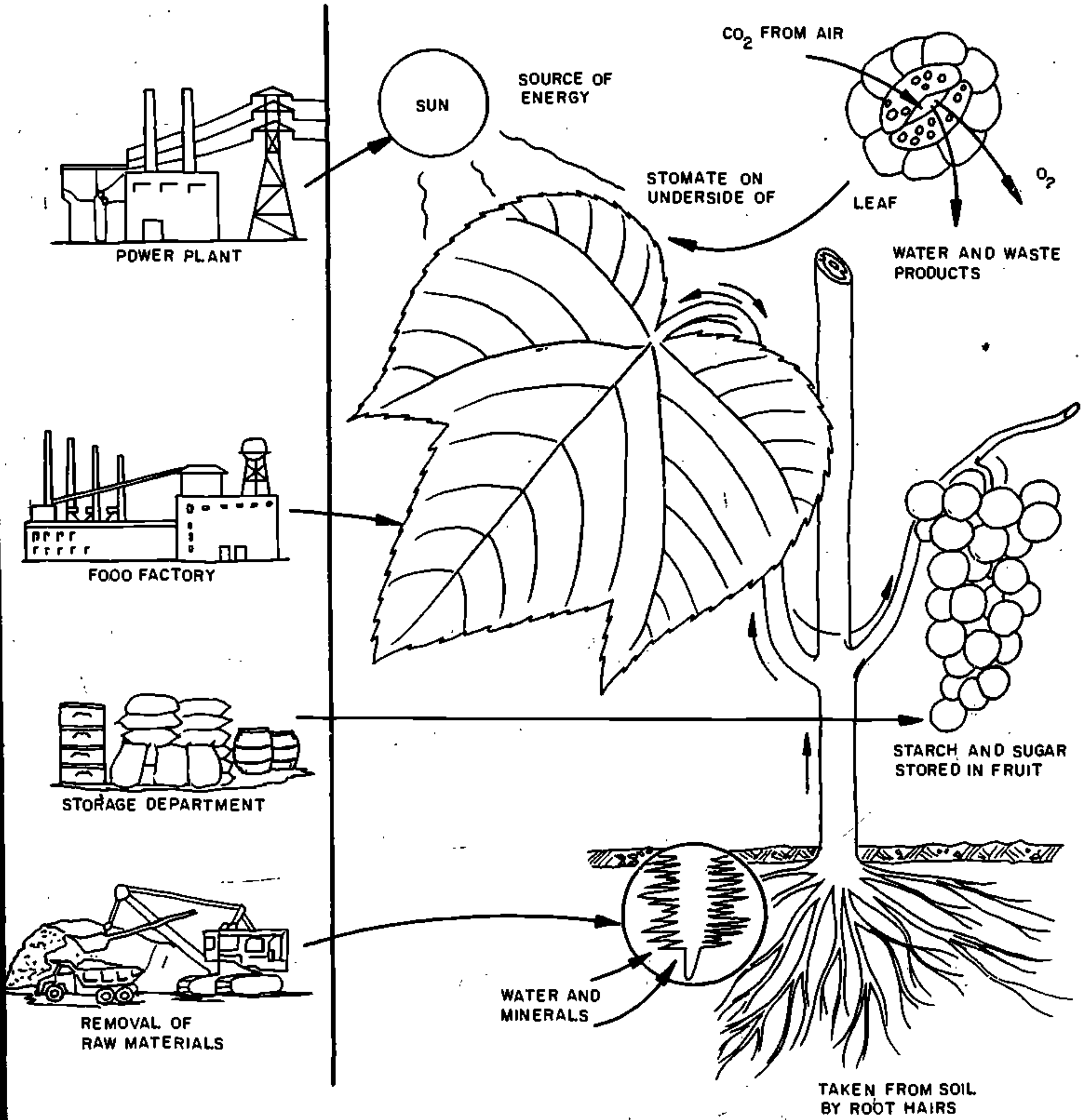
2. Chlorophyll is necessary.

3. Light energy is stored.

4. Oxygen is liberated.

5. Carbohydrates are formed.

Transpiration may be defined as the emission of water vapor from the internal tissues of living plants. The degree to which water is lost from plants depends on the nature of the cell wall. From tender growing parts of the plant such as the leaf, the loss of water by transpiration takes place quite rapidly. The greatest loss of water takes place from the small pores or stoma of the leaf. Beneath each stoma is an air cavity surrounded by cells which are loosely arranged. The water moves into the air spaces and passes into the outer air through the stoma. The stoma have guard cells, the opening and closing of which is controlled by the living protoplasm. When the guard cells are highly turgid or liquid filled, the stomata are opened and transpiration is great. When the guard cells are least turgid the stomata are closed and transpiration is negligible. Transpiration is affected by the following factors:



PHOTOSYNTHESIS

Figure 45

1. The intensity of light.

2. The humidity of the atmosphere.

3. The temperature of the soil and air.

4. The movement of air.

5. The water content or soil moisture content of the soil.

Sometimes a comparison is made between the total amount of water transpired and the total dry weight of the plant. The value obtained by dividing the weight of the water transpired by the dry weight produced is called the water requirement of the plant. In other words, it is the number of pounds of water used by the plant in producing one pound of dry matter. (This value varies greatly in many plants as well as in the same plant under different conditions, but usually has a value of two hundred to five hundred pounds of water to produce one pound of dry matter for most crop plants growing in humid regions.) However, some plants may require as much as one thousand pounds of water to produce one pound of dry matter.

Transpiration is the elimination of water in vapor form. However, water is sometimes eliminated by the plant in liquid form. This process is called guttation. Guttation generally occurs under atmospheric conditions that normally check transpiration. It is particularly pronounced on cool humid nights following hot days. The water usually forms in drops along the edges or tips of leaves where it is sometimes mistaken for dew.

Respiration is the process of taking in oxygen and giving off of carbon dioxide, for the purpose of releasing energy in plants. It is basically the reverse process of photosynthesis - carbohydrates are oxidized and broken down instead of being produced. The most important aspect of respiration is the consequent release of energy necessary for growth and maintenance of the plant. The respirating processes are controlled by enzymes formed in the protoplasm.

Respiration goes on both day and night. During the day photosynthesis normally proceeds at a faster rate than respiration, so that the carbon dioxide liberated in respiration is more than balanced by the oxygen liberated by photosynthesis. At night the plant gives off carbon dioxide, since respiration continues during the night, while photosynthesis ceases in the dark.

F. STEMS

The most important functions of the stem are probably mechanical support of the leaves, flowers, and fruits, and the conduction of water, inorganic salts, and food materials. The leaves carry on the process of photosynthesis. After the foods are made, the stem again provides the pathway through which these foods are removed from the leaves, and carried to other regions of the plant. Similarly, the stem supports the flowers, fruits and seeds, and provides the conducting channels through which these organs are supplied with necessary food for development. In addition, stems sometimes serve as food storage organs in the plants. The stems of some species of plants are also used for water storage. At times, the stem also serves as a means of propagation. While most stems are erect aerial structures some remain underground, others creep along the surface of the ground, and still others are short and inconspicuous.

True stems arise from buds. They have nodes and internodes. They bear leaves, buds and sometimes roots at the nodes, and have characteristic markings such as leaf scars, bud scale scars, and lenticels. A detailed diagram of the stem is shown in Figure 46.

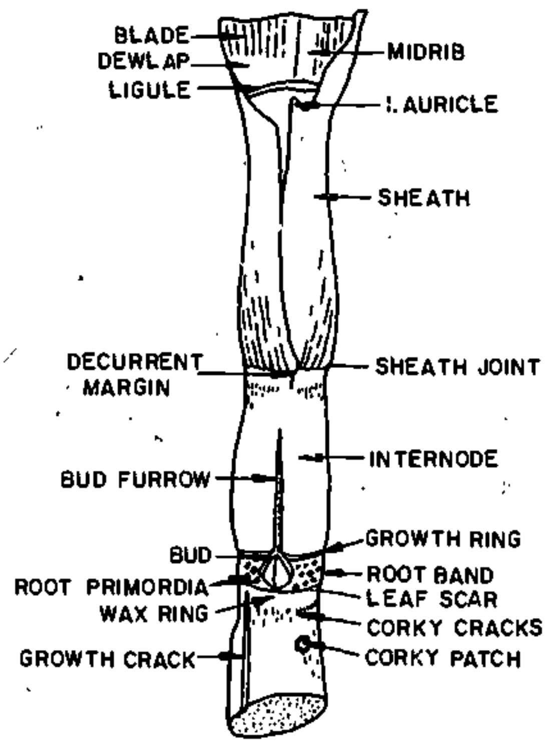


Figure 46

Buds are undeveloped shoots often in a dormant condition. In many plants the more prominent buds from which the major growth of the stem takes place are dormant during unfavorable growing conditions of late autumn and winter. At such times they are protected by a series of overlapping scales. These are called bud scales. Some buds give rise only to vegetative shoots consisting of stems and leaves. Such buds are usually called leaf buds. Others may develop flowers only. These are called flower buds or fruit buds. Terminal buds are buds occuring at the tips of branches. They are found on most plants and are often the largest buds on the plant. They usually give rise to the principal growth in the length of plants or branches bearing them. Lenticels appear on woody stems as small openings or pores. They function in the exchange of gases between the interior of the stem and the surrounding atmosphere.

Typical stems exhibit wide variations in size, form and structure. In length they vary from less than an inch to several hundred feet. In thickness, they vary from almost hairlike structures, to trunks of trees fifty feet and more in diameter. Some stems are tender, fleshy, or watery while others are hard and woody. The classification of plants into herbs, shrubs, and trees depends on the size and woodiness of the stems. Herbs are low growing plants, the stems of which are generally succulent or fleshy although the older ones may develop woody tissue. Shrubs and trees have woody stems, but shrubs branch profusely near the base and do not grow as large as trees.

Stems, like leaves and roots, may appear in different forms and also perform functions in varying ways. Such deviations are widespread and numerous. Two principal deviations will be considered here - underground stems and aerial stems. There are four principal kinds of underground stems:

1. Rhizomes or root stocks
2. Tubers
3. Corms
4. Bulbs

The rhizome or root stock, the least modified form, is merely a horizontal stem growing beneath the surface of the soil. In some cases, it is only partly covered. Though often called roots, rhizomes are really stems, as evidenced from the fact that they consist of a series of nodes. An example is Canada thistle and quack-grass. When cut up as in plowing and cultivating, each small piece produces a new plant. This feature makes such plants noxious weeds and very difficult to eradicate.

When rhizomes become enlarged at the growing end by the accumulation of stored food, tubers are produced. An example of this is the potato. Tubers are the principal organs of food storage in plants which produce them. Potatoes are regularly propagated by cuttings of the tubers.

Corms or solid bulbs may be illustrated by the crocus. It has a very short thick rhizome or root stock. Buds are produced at the upper nodes and roots from the lower surface. The buds produce the new plant.

The bulb may be regarded as a stem reduced to a single bud consisting largely of fleshy leaf scales. When the leaf scales extend completely around the bulb, as in the onion, leek or tulip, the bulb is said to be coated. When numerous narrow scales do not completely encircle the stem as in the lily, the bulb is said to be scaly.

Aerial stems may be unusually long as in plants with climbing or creeping stems. Climbing stems generally are attached to some support and often climb by means of special devices. Creeping stems or stolons, trail along the surface of the ground and take root at the nodes. Examples are strawberries, white clover, and buffalo grass.

Stems also may be thornlike. Thorns, which are modified stems, usually arise in the axils of leaves. These take many forms and shapes and can be dangerous, uncomfortable and poisonous.

G. ROOTS

The root is the part of the plant body which ordinarily grows downward into the soil, anchoring the plant, and absorbing water and inorganic salts in solution. Roots are not necessarily underground structures. The "prop roots" of corn and the "air roots" of orchids are examples of true roots that normally remain partly or completely above ground. Unlike stems, roots do not bear leaves and buds and are not divided into nodes and internodes. For this reason, roots usually branch in an irregular manner. Roots, under certain conditions, develop adventitious buds which give rise to leafy shoots. Such shoots are produced very irregularly and often in profusion when the roots of plants like poplars, black locust, and apple are exposed or near the surface of the ground.

Roots are used by different kinds of plants in many ways but the functions of most roots are: absorption, conduction, anchorage, and storage.

Perhaps the most important function of roots is the absorption of water and inorganic salts. Since the higher plants grow almost exclusively on land, it is necessary for them to be in direct contact with the supply of water and inorganic salts that exists in the soil. Only the youngest roots of the plant are ordinarily concerned in absorption. Trees must constantly develop new roots if absorption is to continue.

Once these materials are absorbed from the soil, the root serves to pass them on to the stem. The xylem of the root is continuous with that of the stem. By this means, water and inorganic salts can be distributed throughout the plant.

While it is important to have a part of the plant in contact with the supply of water and inorganic salts, it is also important to have other parts placed to receive light and air. This is accomplished in many plants by upright stems and spreading branches. Roots support the stem by anchoring it to the soil. A deep rooted plant can serve this purpose better than a shallow rooted one. Tap rooted trees more readily withstand heavy wind than do surface rooted plants.

In most plants, part of the food manufactured above ground is carried to the roots and stored there for future use. Such storage is particularly found in biennial and perennial plants. Biennials like the beet and cabbage, usually develop a rosette of leaves during the first year of their growth. During this period large amounts of food are made and stored in the roots. The following year the stored reserves are used to develop an upright shoot on which flowers and seed are produced.

Very often roots become large and fleshy as the result of food storage. This is true of sweet potatoes, radishes, beets, turnips, and many others. The internal structure of such roots becomes highly modified to accommodate the stored reserves. Many of these plants are of considerable economic importance.

Since many roots are capable of developing adventitious buds which give rise to leafy shoots, roots are sometimes a means of propagation plants. This is called asexual reproduction. This enables man to propagate many forms of plants that otherwise might be difficult to reproduce. Sweet potatoes are regularly grown from root cuttings just as the white potato is grown from tuber or stem cuttings. Some plants, when cut off at the roots, develop adventitious buds which give rise to new plants. This phenomena is sometimes utilized in the propagation of roses and other plants.

Roots can be classified as primary roots, secondary roots, and adventitious roots. They may also be classified as tap roots, fibrous roots, and fleshy roots.

The root that is first put out by a germinating seed usually grows directly downward and is known as the primary root. The branches from this primary root are called secondary roots. Secondary roots orginate much farther from the root apex than do primary roots.

Many grass stems root at the nodes or joints if the stems become prostrate. Such plants as the geranium, carnation, willow, poplar and rose will develop roots if placed in moist sand or water. All roots so developed are to be classed as adventitious roots. In the cereals, adventitious roots develop at the junction of the root with the stem. Sometimes the first nodes of the stem start the principal roots of the plant.

If the primary root remains the largest root of the plant and continues its growth to become the main root, it is known as a tap root. Rag weeds, burdock, dandelion, oak and hickory trees all have well developed tap roots.

Monocotyledonous plants usually do not develop tap roots. When numerous long slender roots of about equal size are developed they are known as fiberous roots. In this case no one root is the largest. Many grasses have fiberous root systems.

Recent studies have shown that the extent of root development is much greater than former knowledge seemed to indicate. In many cases the roots are longer, more extensive and greater in weight than the tops of the same plant. A single corn root for example has been found to occupy 230 cubic feet of soil. The species of plant in itself is important. Many plant roots penetrate three, four, or five feet. Alfalfa occasionally has roots extending to a depth of 40 to 50 feet into the soil. Numerous environmental factors determine the direction and extent of growth. These include gravity, light, temperature, soil texture, soil minerals, oxygen supply, and moisture. Every root is subjected to all of these factors. The actual growth of the root is the result of the action of these factors.

In response to gravity, roots generally tend to grow downward. This is known as positive geotropism. If subjected to one-sided illumination, roots grow away from the light and exhibit what is known as negative phototropism. Roots will bend in the direction of the temperature most favorable to their growth, exhibiting what is termed as positive thermotropism. Roots develop best in a loose fertile soil.

Oxygen must be available for the respiration of roots. Experiments on a number of plants show that growth ceases when oxygen is removed. Roots at great depth in the soil, in waterlogged soils, or in very compact soils are likely to suffer from lack of oxygen.

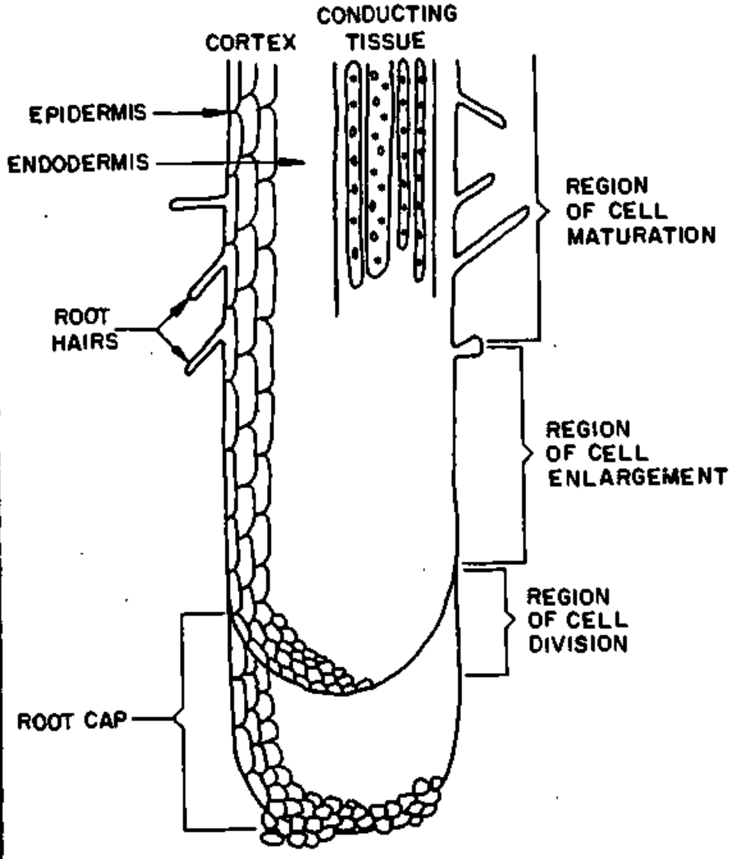
Roots do not seek water but will continue to grow in the direction of moisture supply. Moisture is an important factor in determining direction, depth of penetration, and lateral spread of roots. In desert regions annual plants seldom penetrate more than a few inches with the greatest development in the upper two or three inches. However, where rainfall is great and where much of the rain infiltrates into the soil, roots will penetrate much deeper.

Structure of roots

When seeds are germinating the first structure to emerge from the seed is the root. Roots of this kind are usually white or colorless, more or less rounded off or pointed at the tip. Figures 47 and 48 are drawings of a root tip illustrating the root hairs. The tip itself is covered with a thimble-like tissue known as the root cap. The root cap is a distinctive root structure found on practically all roots but never found on any other plant organ. It is a loose tissue acting as a cap or protective layer for the growing point of the root.

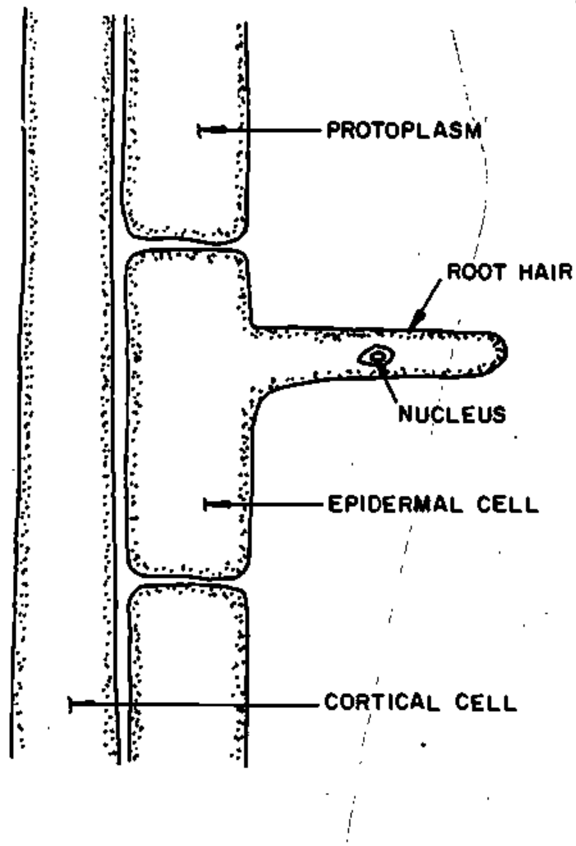
Behind the root cap will be found a multitude of fine white hairs radiating outward from all sides of the root. The shortest root hairs are nearest the root cap. Farther back they increase in size until the maximum length is reached. The area covered by these root hairs is known as the root hair zone. Beyond this narrow zone no hairs are visible. Near the root apex, new hairs are continually being produced. In the older region of the root hair zones, the hairs are dying and disappearing. The root hair zone is constantly moving forward keeping pace with the growth of the root point or apex. Root hairs grow until they come in contact with some solid substance such as a soil particle and then flatten out, thus presenting the greatest possible absorbing surface coming into intimate contact with the film of moisture which surrounds the soil particle. As a result of this response, the root hairs assume irregular forms, clinging tightly to the soil particles. It is almost impossible to remove a plant from the soil without leaving behind most of the root hairs. For this reason, plants pulled out of the soil and transplanted usually wilt, unless the transpiring surface is reduced by pruning or cutting back. The actual size and the amount of production of root hairs depends upon the conditions under which they are formed. The kind of plant, temperature, moisture, oxygen supply, and the concentration of various minerals in the soil solution are important factors. A slow growing root usually has a greater density of root hairs per unit area than does a fast growing root. A saturated soil generally suppresses root hair development. Most plants develop root hairs best in a well aerated moist soil.

Most roots are normally underground structures. In certain species of plants they are found partly or entirely above ground. These are spoken



LONGITUDINAL SECTION
OF A YOUNG BARLEY ROOT

Figure 47



ROOT EPIDERMAL CELL
SHOWING ROOT HAIR PROTRUDING

Figure 48

of as aerial roots. When the stems of corn have started to grow rapidly, the first few nodes above the soil send out a cluster of stilt-like roots to the soil. These roots help to support the tall stem but they also grow into the ground and function in absorption of water and inorganic salts. Roots of this type are called prop or brace roots.

The climbing roots of plants such as poison ivy, english ivy, etc., are also a form of aerial root.

Of the various materials the plant gets from its environment, none is more important than water. Plants are composed of from fifty to eighty-five percent water. Plants are constantly losing large quantities of water by transpiration. This water must be supplied through absorption by the roots if wilting of the plant is to be prevented. Water is the medium by which foods are transported from one part of the plant to another. Without a constant supply of water the plant could not carry on any of its physiological activities.

Water does not exist in a pure form in soil but is a solution containing various solutes, clay particles, dissolved nutrients, etc. This water in the soil is referred to as the soil solution. The osmotic pressure of the soil solution averages from .2 to 1 atmospheres of pressure in humid regions.

By means of tiny root hairs, the plant receives water and nutrients from the soil by the process of osmosis. As the water is aborbed by the root hairs the cells in the root hairs tend to become more and more turgid. As this pressure rises, water passes from one root hair cell to another. This cell in turn passes it on to the next cell by osmosis and so on until it reaches the xylem. Through the xylem, the water is carried to all parts of the plant. Thus the relationship of the root to the stem, the stem to the leaf, the leaf to the flowering parts or seed producing portion of the plant is seen. Each in turn has a definite function to perform. This enables the plant to act as a factory in converting minerals and moisture from the soil and carbon dioxide from the air into food which will enable humans and animals to live more abundantly.

Roots growing in the soil have important effects on the chemical and physical nature of a soil. The decay of roots furnishes available nitrogen and other substances for later crops. By this means, considerable amounts of organic matter are added to the soil each year. This organic matter influences both the physical and chemical properties of the soil.

H. FLOWERS

The flower is the structure concerned in the sexual reproductive processes of plants. Flowers lead to the production of fruit and seed.

Flowers may be composed of as many as four different sets of organs which are: sepals, petals, stamens, and pistils. When all four sets of organs are present, it is called a complete flower. If any one of these sets of organs is lacking, the flower is said to be incomplete. If the flower lacks either stamens or pistils, it is said to be imperfect. When both the stamens and the pistil are present, the flower is said to be perfect, regardless of whether sepals or petals are present. Therefore, all complete flowers are perfect. Incomplete flowers may be either perfect or imperfect, depending upon whether or not both stamens and pistils are present. In the case of imperfect flowers, stamens alone may be present in one flower and pistils alone in another flower on the same plant. These flowers are unisexual and the plant is said to be monoecious. If the male or staminate flowers are produced on one individual plant and female pistillate flowers on another, the species is said to be dioecious. Monoecious species are much more common. An example of this species is corn. Occasionally a flower forms with no stamens or pistils. Such flowers are said to be sterile and never produce seed.

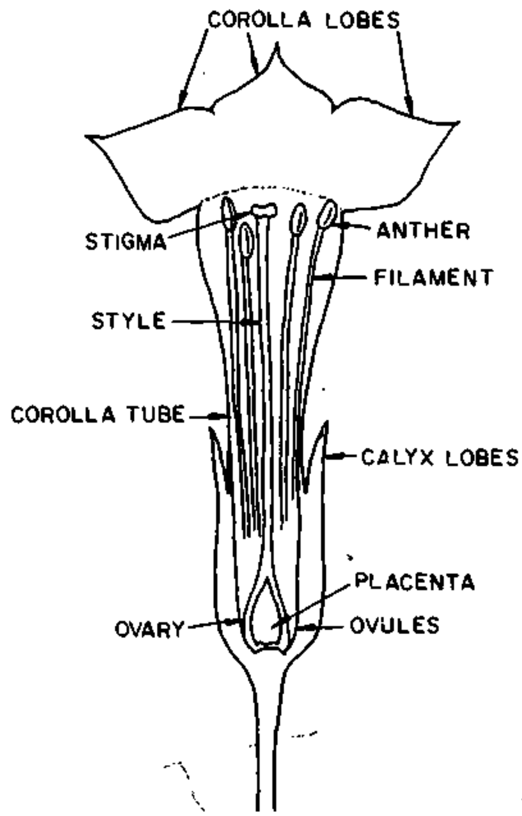


Figure 49

Sepals and petals, or at times sepals alone, constitute the perianth. These parts are frequently spoken of as accessory flower parts. They are not essential to seed formation. Stamens and pistils are regarded as the only essential organs of the flower. Both must be present, either in the same or in different flowers, in order to have sexual reproduction and the resulting formation of seed. The stamens are the male portion of the flower. Each stamen consists of a stock or a filament bearing an anther. The anther produces the pollen.

The pistil is the female portion of the flower. The enlarged basal region is called the ovary. The ovary produces the ovules. The apex is known as the stigma, and that portion connecting ovary and stigma is known as the style. The function of the stigma is to receive the pollen grains carried to it by various agencies such as wind, insects, gravity, and so on. When the pollen grains are shed from the anther, they reach the stigma of the same or of another flower. This transfer of pollen from anther to stigma is known as pollination. In the case of imperfect or unisexual flowers, the transference of pollen from the anther of one flower to the stigma of another occurs. This is called cross-pollination. Perfect flowers, or flowers which have both male and female parts, are generally self-pollinated, that is pollen transfered from anther to stigma on the same flower.

The time that elapses between pollination and fertilization varies in different species. It could be less than 24 hours or extend over a period of several months. Most frequently, it takes from two to five days.

I. SEEDS

A seed has been described as a plant that is packaged for shipment. Above all else, it is a way of survival of a species. Seeds are a vehicle for the spread of new life from place to place. Seeds are food for man and animals. They are wealth and a never ending source of wonder.

One of the factors involved in crop production over which a farmer has considerable control is the choice of seed. He has the ability to choose seed of a proven variety and one which is pure and free from insects or plant diseases. A poor seed choice results in bad yields and an economic loss.

Good seed characteristics

The seed a farmer chooses should have the following characteristics:

1. It should be pure and free of varietal mixture.

2. It should germinate rapidly to give strong vigorous seedlings.

3. For the variety, the seed should be large and plump.

4. There should be absolutely no noxious or objectionable weed seeds present.

5. It should contain no insects, insect eggs, or disease spores in or on the seed.

6. The seed should be uniform in size.

7. It should be free of rocks, chaff or trash.

In order to germinate, seeds must have proper amounts of temperature, moisture, air, and sometimes light. If any of these conditions are not right, a seed will lie dormant and not germinate. When the farmer sows his seed, he wants to be sure that it will germinate and produce a good stand.

Many seeds have a built in, delayed-action mechanism that insures the seeds will remain dormant until the proper conditions for germination have arrived. The nature of this dormancy varies greatly among plants. It can be due to a moisture resistant "hard" seed coat. Some seeds must go through a long period of cold temperatures before they will germinate. Other seeds will lie dormant in the soil until they are exposed to light. Some will fail to germinate immediately after they are separated from the mother plant because they are not completely mature. Dormancy in seeds may protect them, but it can be a problem in commercial production when quick, vigorous germination at the time of planting is desirable.

One way to estimate the kind of stand obtainable in the field is to run a germination test. To do this, a representative sample of seeds is taken from the lot to be sown. These seeds are placed under conditions of good aeration and abundant moisture for a few days until the embryo has had a chance to expand. The seeds that have germinated are counted and the percentage calculated.

Attention should be paid to the vigor of seedlings. Vigorous seedlings that germinate rapidly and have thick hypocotyls and healthy primary root systems, are less likely to succumb to seedling diseases.

Seed tags

All seed from the United States and a number of other countries must be labeled with certain information. This is for the protection of the buyer so he knows what he is buying. The information usually contained on the tag is:

1. Name of each kind of agricultural seed in excess of five percent.

2. Percent of other crop seeds.

3. Percent of weed seeds.

4. Name and approximate number of noxious weed seeds.

5. Percent inert matter.

6. Percent germination.

7. Month and year of test.

8. Name and address of seller.

9. Lot number.

Certified seed

Whenever seed is discussed, the word "certified" ~~always comes~~ up. What is "certified seed"? It is seed of a known genetic identity. This is accomplished by a system of records and inspection. Pedigree records are kept of the planting stock used. Inspections are made in the fields and during all phases of production, harvesting, and cleaning. Each bag is sealed and tagged with a certification tag after it is tested and meets the requirements for purity and germination. Without such a system, varieties tend to become mixed and contaminated and lose their identity. Through certification, it is possible to buy seed from many sources, move it all over the world, and still be certain of having the variety marked on the label.

Seedling establishment

Choice of good seed alone, will not guarantee good crop yields and high quality produce. Regardless of how good the seed is, if it is planted too early, too late, too thick or too thin, maximum potential will not be realized.

Each crop should be planted at that time of the year when the different stages of its development will be most accurately correlated to the most favorable weather conditions. Temperature and moisture are of special importance, while in many species light and day length play an important part. Control of weeds, plant diseases and insect pests should be kept in mind when selecting planting dates. Although not always true, the earlier a crop is planted without danger of frost damage, the better it will perform.

High yields are dependent upon good vegetative development of the plants prior to the beginning of maturation and seed development. Therefore, the longer the period of vegetative growth, the higher the yield.

Soil moisture at seeding time should be ideal for plant emergence. As the season progresses, soil moisture declines, especially in the surface layers. As a result, later seedings must often be planted deeper than earlier ones. There is a limit to how deep a seed may be placed. In general, it is not wise to bury seed more than three or four times their diameter. Small seeds, therefore, cannot be planted as deeply as larger ones.

Temperature, on the other hand, becomes more favorable as the season advances. With the high moisture level and low temperatures of early spring, low oxygen also prevails. Many seeds tend to rot under these conditions. Planting dates must be delayed until the soil is warm enough to insure rapid germination.

Rate of planting is especially critical for row crops. With broadcast crops, like small grains, tillering is more prevalent when seeding rate is low and tends to compensate for the lowered rate. Degree of tillering is also influenced by soil fertility. For crops that tiller freely, it is generally recommended that seeding rates be higher on poor soil. For crops like corn, beets, and potatoes which do not tiller, higher seeding rates would be recommended on the fertile soils. Corn planted at higher rates, produce smaller ears but higher yields.

J. VEGETATIVE REPRODUCTION

Plants may be propagated in two general ways; by seed or vegetatively. In most farm crops the use of seed is the most economical and efficient way. With a few crops, however, reproduction by vegetative means is necessitated since seedlings are not always true to type and some seed cannot be produced or harvested economically.

Crop plants produced vegetatively or asexually, and the plant part used to propagate them, include the following:

1. Roots - sweet potatoes, cassava, kudzu.
2. Tubers - potatoes, Jerusalem artichokes.
3. Stolons - Buffalo grass, Bermuda grass.
4. Rhizomes - Bermuda grass.
5. Stems - sugar cane, Elephant grass, cassava.

Cuttings of stems and tubers should be made in such a manner that enough buds or eyes are available for ample vegetative growth. Care should be taken so that the seed stock is not buried too deeply.

K. WEED CONTROL

A weed is generally defined as any plant that is out of place. The chances of a farmer losing his entire crop to weeds is relatively remote,, nevertheless, weeds cause a great deal of damage each year.

The chief losses caused by weeds are:

1. Reduction in yield due to competition by the weed for needed light, water, and mineral nutrients.

2. Decrease in crop quality.

3. Costs of weed control.

4. Losses due to disease and insects harbored and protected by the weeds.

5. Decrease in land value.

6. Increase in taxes necessary to support county and state eradication programs.

Most weeds are relatively easy to control. Some weeds, once established, are extremely difficult to keep in check. These latter species are frequently termed noxious weeds. The plant is removed from the "noxious" list only after an effective control measure is developed.

The ideal method of weed control is to prevent their establishment. Once weeds are established, they can be combatted through mechanical means such as hoeing, cultivation, and clean tillage; through ecological methods such as crop competition; and through chemical methods of control. The method of control used would depend on the species of weed and the nature of environment. In most cases, a combination of methods gives the best results.

The key to prevention rests with the ability to identify the weeds as seeds, seedlings, and as mature plants. Whenever uncertified seed is purchased, it should be thoroughly examined for the presence of weed seeds, especially noxioue weeds. If any species of weed seed is found which is not already present on the farm, the seed should be rejected unless it can be recleaned prior to use. Equipment such as combines should be thoroughly examined before coming onto a farm. Hay should be examined for weed content before it is purchased.

In most cases, eradication of a weed species is not economically justified. This would be true of small relatively harmless weeds or one that is already widely established on a farm. It would not be true of a noxious weed not yet well established.

Listed among mechanical methods of weed control are hoeing, pulling, intertillage, blind tillage, clean tillage, smothering with water and mulches, and controlled burning.

Timeliness is an important consideration in mechanical weed control. Cultivation of some annual weeds should be done as early as possible, sometimes even prior to emergence. With some perennial weeds, multiple tillage is required. To help reduce the food reserves in the roots, the plant may be allowed to emerge and grow for about two weeks, depending on the species and environment, and then destroyed.

Ecological control methods have not been recognized by man until recent years. These methods include crop competition and biological control.

In very recent years, inexpensive chemicals have cut the cost of controlling weeds in some crops to a small fraction of former costs. The most spectacular of these has been 2, 4-dichlorophenoxyacetic acid - commonly called 2, 4-D. Although 2, 4-D is relatively new, chemical weed control is not. Until recently, however, chemical weed control was too expensive to be widely used on a field basis.

Chemical weed killers may be classified under two headings: non-selective and selective. The non-selective herbicides are chemicals which are toxic to all plants. Selective herbicides on the other hand, are chemicals which destroy one type of plant without seriously injuring another.

Some species of plants are more susceptible to injury by any specific herbicide than are other plants. Because closely related plants are similar to each other morphologically and physiologically, members of the same botanical family tend to be either susceptible or tolerant to a given herbicide.

The number of effective chemical compounds used to control weeds is constantly increasing as testing of herbicides continues. As the numbers increase, the decision becomes more difficult in selecting the most effective chemical. In most cases, technical advice should be sougbt.

L. PLANT DISEASES

Any abnormal condition in the growth or development of a crop is called a plant disease. Altbough some of these abnormalities are caused by environmental factors, most are caused by living agents which parasitize the plant.

Various external signs and symptoms indicate the presence of a plant disease. Some of the most common are:

1. Discoloration
2. Perforated leaves
3. Wilting
4. Necrosis, or the death of some plant tissue
5. Dwarfing or atrophy of plant parts
6. Increase in size, or hypertrophy, of plant parts
7. The replacement of plant organs by new structures
8. Complete destruction of some of the plant organs
9. Mummification
10. Alteration in plant habit or symmetry
11. Dropping of leaves, blossoms, fruits or twigs
12. Production of excrescences and malformations, such as galls, cankers, rosettes, etc.
13. Production of an exudate
14. Rotting of a tissue

The organisms which incite plant disease can be classified under six headings: viruses, bacteria, fungi, algae, protozoa, and nematodes.

Plant diseases reduce the value of crops by reducing yield per acre, reducing quality, or by making the plant more susceptible to other kinds of injury, such as winter killing.

Control methods for plant diseases include: use of only certified seed, crop rotation, plant breeding and use of chemicals.

Preventative methods of plant disease control have been used effectively in several countries during recent years. The principle is simple, easy to put into operation, economical and effective. These countries inspect plants coming into the country and examine them for disease symptoms. Many plants must be grown for two years under quarantine for possible disease symptoms not readily detectable. The use of certified seed is one of the surest guarantees a farmer can have that the seed or plant propagules brought onto his farm will be free from plant disease.

If diseases are soil borne, the most effective way to control them is by crop rotation. By planting a crop which is not susceptible to the disease, the causative organism is reduced in numbers. A lesser amount of the disease occurs the next time the susceptible plant is grown. New chemicals are constantly being tested for effectiveness as soil fumigants. With the development of such fumigants, it is becoming possible to control soil borne diseases without crop rotation. This enables a farmer to specialize in one crop.

Plant breeding is a successful tool in controlling plant diseases in crops in which a variation of resistance to the disease exists. Plant breeding is especially successful in combating diseases caused by viruses, bacteria, and fungi. When a disease resistant variety is produced, farmers have not only gained the protection against the economic loss the disease can cause, but have also saved the cost of using fungicides as well.

The exact nature of disease resistance in plants is not known. In some cases the resistance may be due to morphological adaptations of the plant: size and location of the stomata, presence of hairs, thickness of the epidermal cells, etc. In other cases, it may be due to physiological adaptations, i.e., substances which are toxic to the disease organisms.

Whether or not a plant becomes diseased will depend on certain factors of environment, such as the abundance of the diseased organism, humidity, temperature and wind. Frequently, plants may escape the disease even though they are susceptible to it.

Many different chemicals are used to control plant diseases. Some are made to be applied to the plant, while others are applied to the soil.

Seed and foliage-application chemicals have been quite effective in controlling diseases, especially those caused by fungi. Soil fumigation has only recently been developed but is proving very effective against nematodes.

In general, plant diseases can be classified by the causative organism. A crop disease is usually caused by either a virus, a bacteria, or a fungi. Very rarely are diseases caused by algae or protozoa.

UNIT III - ENTOMOLOGY

A. INTRODUCTION

The protection of farm crops from destructive insects is one of the most important requirements for successful farming. From the time the seeds are planted, throughout the period of the growth of the plants, and even after the crop is harvested, insects cause an economic loss. Different crops vary in their susceptibility to insect damage but none entirely escape attack. Insect damage may result in total crop loss. This loss may even exceed that loss indicated by poor stands, unthrifty growth, reduced yields, or poor quality.

Such insects as the grasshopper, or "locusts" as they are called in the eastern hemisphere, boll weevils, corn borers, etc., are quite familiar to a lot of people because of the spectacular damage they cause. In addition to this type of insect outbreak, there is the continual drain on practically all crops caused by lesser and more obscure forms of insects whose work may be unnoticed, such as root infesting insects and sap sucking species.

The larger, more conspicuous insects such as armyworms, cutworms, and beetles, as well as signs of their work, are quite familiar to most people. The injury caused by the minute forms are often mistaken for such things as poor seed, unfavorable soil conditions, or plant diseases. It is now known that many serious plant diseases are carried and spread by insects.

Agriculture in general favors the multiplication of insect pests because many farm crops are not native to the area in which they are grown and have not developed an immunity to the particular pest. Another important reason for the growing seriousness of the insect problem is the introduction of injurious species from abroad. The increased volume of commerce from abroad and the speed of airplane travel has greatly increased the possibility of accidental introduction of insects.

Man's survival depends, to a certain extent, on some insects. Insects produce honey, silk, shellac, various dyes and drugs, and are responsible for the direct production of much of our food products. There would be little tree-fruit without the aid of insect pollinators. Over fifty varieties of vegetables are dependent upon insect pollination. Most of our fresh water fish would disappear if insects were to vanish. The majority of insects are beneficial to the farmer.

Successful insect control depends first of all upon a knowledge and understanding of the insects themselves. Each insect species or closely related group has its own characteristics and habits. These characteristics and habits have a great deal to do with the success encountered in controlling them.

B. INSECT CLASSIFICATION AND STRUCTURE

An insect belongs to a large group of animals characterized by a body divided into three parts: head, thorax, and abdomen. They have three pairs of jointed legs, one pair of antennae and from none to two pairs of wings.

Other classes of animals mistaken for insects due to certain similarities are:

1. Class Arachnida - Spiders, ticks, spider mites, etc. These are characterized by having only two main body parts and four pairs of jointed legs. They never have wings or antennae.

2. Class Crustacea - Lobsters, crayfish, sow bugs and pill bugs. This class is characterized by having five or more pairs of jointed legs, are wingless and may have two pair of antennae.

3. Class Chilopoda - The centipedes. This class of animals is characterized by having many body segments. Each of the body segments, with the exception of the head, has one pair of legs. They have one pair of antennae but the wings are absent.

4. Class Diplopoda - The millipedes. Millipedes are characterized by having many body segments, each with two pairs of legs. They have one pair or no antennae and wings are absent. Millipedes are rarely considered a pest.

Because many insects are beneficial and others are of little economic importance, it is essential that they are correctly identified. Common names vary from place to place and with conditions. For this reason, scientific names are used by entomologists. Proper identification is also important because chemical control may vary with certain closely related species.

Instead of an internal skeleton made up of bones, the insect has an external or exoskeleton. This cuticle or exoskeleton has an outside waxy or oily layer which helps to make it waterproof. This oily or waxy layer plays a part in the control of insects. When an insect walks over a surface sprayed with a contact insecticide, the oil on the surface of the cuticle dissolves some of the insecticide deposit from the surface. This dissolved insecticide is then absorbed through the cuticle of the insect and into the body fluid and the insect is poisoned.

The insect respiratory system is unlike that of the warm-blooded animals. It is a series of tubes which run to various organs of the insect's body some of which open to the outside. Fumigants used to kill insects enter the insect's body through these spiracles. Other control agents such as oil, may plug these spiracles and actually smother the insect.

Insects have several different types of mouthparts. The type of damage done by an insect pest depends upon the type mouthparts the insect has. These mouthparts are divided into five different categories: chewing, piercing-sucking, rasping, sucking, and lapping.

Insects with chewing mouthparts have a pair of mandibles or jaws which move laterally and can actually bite or chew holes in plant leaves, stems or other parts. Examples of insects with chewing mouthparts are various caterpillars or larvae such as cutworms, armyworms, corn earworms, grasshoppers, and beetles.

Some classes of insects have a sharp beak or needle-like stylet with which they pierce the tissue of plants or animals. These are called piercing-sucking mouthparts. Plant feeding insects of this type suck out the plant sap or juices and may inject a toxin during feeding which cause characteristic symptoms on the plant. Some of these insects may also carry organisms which cause disease, usually viruses. Examples of insects and related animals with piercing-sucking mouthparts are the aphids, leafhoppers, mealybugs, squashbug, fleas, mosquito, etc.

Insects with rasping mouthparts injure the surface of the epidermis of the plant by breaking the walls of the surface cells and allowing the cell content to escape. These insects then suck up the cell sap. This can occur on the leaves, on the flower, or on the surface of the fruit, spoiling the market quality and causing the leaf to curl. Insects with this type of mouthpart are the thrips.

Insects with sucking or siphoning mouthparts are incapable of piercing plant or animal tissue. They merely suck up liquids which are readily available from the surface of the plants or the nectaries found in flowers. Examples of insects with this type of mouthpart are the adult moths and butterflies.

Lapping mouthparts are characterized by being broad and sponge-like. These mouthparts are used for sponging or lapping up liquids and transferring them to the mouth of the insect. Typical examples are adult flies, bees, ants, and wasps.

Because insects may cause damage during only one stage of their life cycle, a knowledge of the life cycle of insects is important. Insecticides might also be effective during only one stage of the life cycle.

C. METAMORPHOSIS

In the majority of insects, there is a change or transformation that takes place before the adult stage is reached. This is called metamorphosis. If no marked changes occur in body form, metamorphosis is said to be gradual or incomplete. The young resembles the adult in body form but may differ in coloration, presence of wings, spines, or body ornamentations. These types of insects are said to have three life stages; the egg, the nymph and the adult.

If the insect passes through marked changes so extreme that the habits and appearance of the young are radically different from those of the adult, it is called complete metamorphosis. Immature insects of this type are known as larva. Common names usually given them are worms, caterpillars, grubs, and maggots. Insects having the complete type of metamorphosis have four life stages; the egg, the larva, the pupa, and the adult. Insects with complete metamorphosis feed in the larval stage but may or may not feed in the adult stage. They never feed in the egg or pupal stage.

Reproduction in insects is very similar to the reproduction of animals. Exceptions are: aphids, certain weevils and other insects who produce young without mating. In some species there are no males.

The ability to produce many eggs and young in a very short life cycle makes it possible for the insect population to build up very rapidly. A common housefly can lay about 900 eggs in her lifetime.

D. INSECT CONTROL

With the tremendous reproductive potential, it is apparent there must be various regulating factors to keep the population reduced. Some of these factors are the natural physical factors of cold, heat, rain, and wind. Insects are killed by various diseases caused by fungi, bacteria, virus, and other organisms. Various predators such as birds, fish, frogs, etc., as well as other insects and spiders, effect what is called natural control. When one or the other of these factors breaks down, insects build up and man must step in with chemical insecticides or some other means of control in order to prevent damage to his crops.

There are hundreds of different kinds of insecticides on the market. These insecticides kill insects by several different modes of action. Some kill by contact, others by stomach poison action, others kill by fumigation. Some insecticides are systemic in action. When sprayed upon plants or around the roots of plants, they are absorbed into the plant and translocated to the stems, branches, leaves and fruit of the plant. When an insect sucks the juices from the plant, it obtains some of the insecticide and is killed.

An insecticide, however, must only destroy the insect. It must not be harmful to the plant, animal, or man. Frequently, there is only a narrow margin of safety between toxicity to the insect and toxicity to the plant or animal. The use of these chemicals on foliage and food crops may result in residues on the feed or food products which may be harmful to animals and man.

The ideal insecticide should not destroy beneficial insects or invertebrate predators and parasites of insects. Sometimes the control of one pest favors the reproduction of another because of the destruction of their natural enemies. Other desirable features of an insecticide are availability, low cost, noninflammability, ready miscibility, and ease of application.

Insecticides are divided into five general groups and are illustrated in Table 3.

It should always be kept in mind that insecticides are poisonous. Certain precautions should always be taken when using them. When applying the more toxic compounds, certain articles of protective clothing should be worn. Many of the more volatile and synthetic organic insecticides are readily absorbed through the skin. Persons handling such compounds should wear clothing which covers as much of the body and head as possible. Rubber gloves should be worn when handling insecticide concentrates or when spraying with the toxic compounds. Rubber footwear should be worn to protect the feet. Since vapors, fine droplets, or dust particles of these insecticides may enter the body through the respiratory system, a proper respirator should be worn. Hands should be washed thoroughly with soap and water every time you fill the sprayer or duster with pesticides. Empty containers should be completely destroyed so they are not used for any other purpose. Pesticides should be stored in a safe place out of reach of children, pets, or persons who are not familiar with them.

TABLE 2

INSECTICIDE GROUPINGS

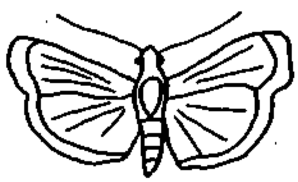
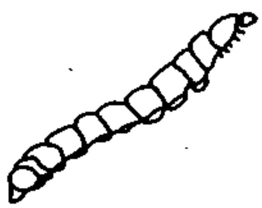
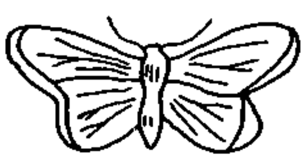
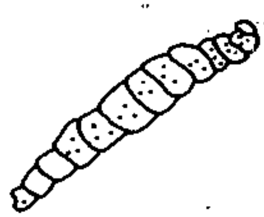
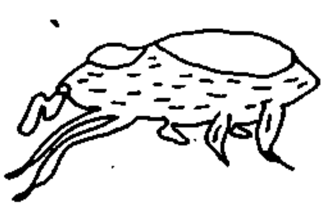
Group	Mode of Action	Toxicity to Warm Blooded Animals	Examples
Chlorinated Hydrocarbons	Contact (stomach)	Low to high	DDT - DDD Toxaphene Lindane-BHC Aldrin-Duildrin Chlordane
Organic Phosphates	Contact systemic stomach fumigation	Low to extremely high	Malathion Phosdrin Parathion Thimet Systox TEPP
Carbamates	Contact (stomach)	Low to moderate	Sevin
Inorganic	Stomach (fumigant)	High	Lead arsenate Calcium arsenate Paris Green Sulfur
Botanical	Contact - stomach Stomach	Low Low High	Pyrethrun Ratenone Nicotine

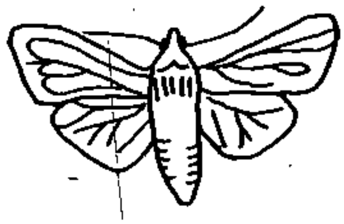
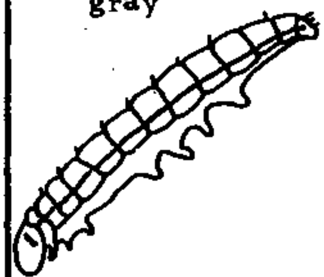
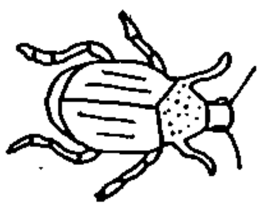
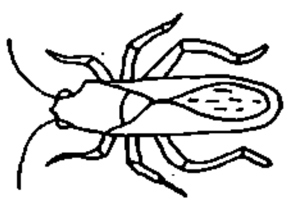
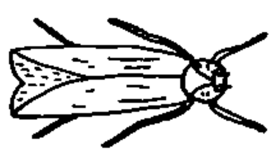
E. COMMON CROP INSECT IDENTIFICATION

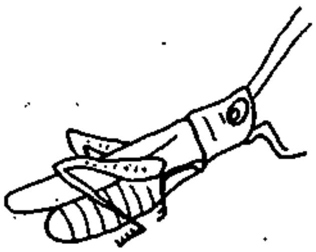
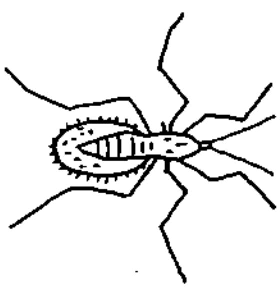
We live in a world with teeming millions of insects - some useful and some harmful. There are about 686,000 known species of insects. Some of the more common useful insects are boneybees, dragonflies, damselflies, wild bees, robberflies, tiger beetles, ladybeetles, silkworms, etc. Insects, of course, can be both harmful and useful. There are many more harmful than useful types. Tbe following Table is a list of the more common insects whicb are harmful to crop plants.

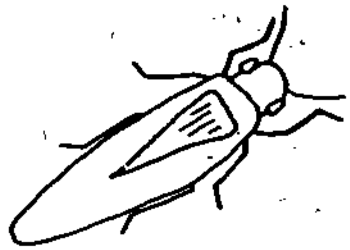
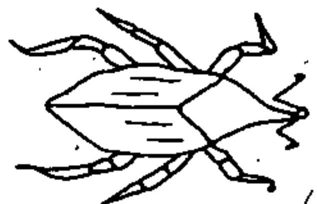
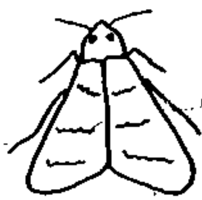
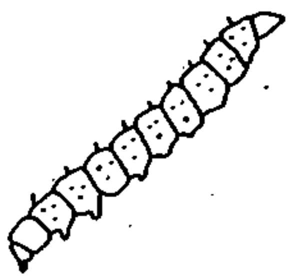
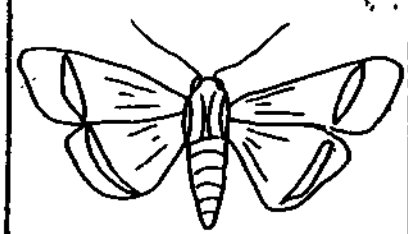
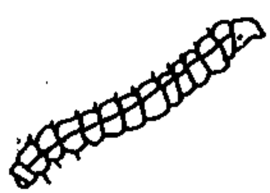
TABLE 3

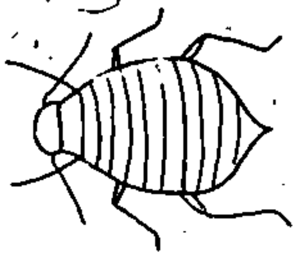
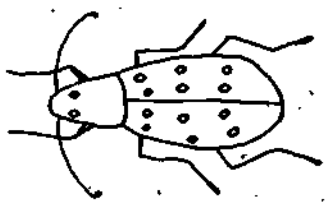
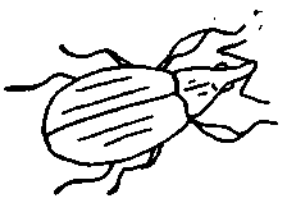
INSECT IDENTIFICATION

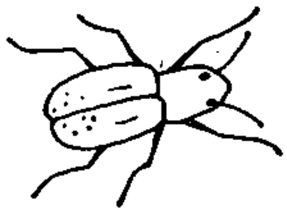
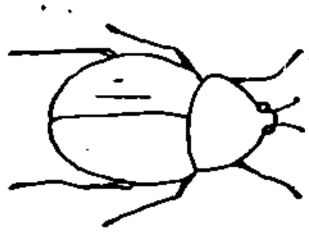
Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Alfalfa Caterpillar (Colias philodice eurytheme)	2" sulphur yellow 	$1\frac{1}{4}$" dark green 	Chews, strips foliage	Alfalfa, other legumes
Alfalfa Webworm (Stenachroia elongella)	3/4" pale brown 	Larva 3/4" greenisb brown 	Chews foliage cover plant witb silken web	Alfalfa, clover soybeans
Alfalfa Weevil (Hypera-postica)	1/8" brown to black 	Larva 1/8" green 	Chews on stems, leaves, and buds	Alfalfa and clover

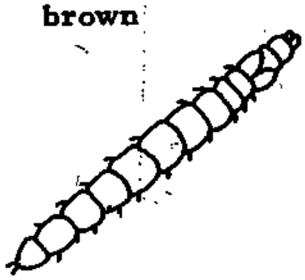
Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Armyworm (Cirphis unipuncta)	pale brown ½" 	2" brownish gray 	Chews foliage strips plants	Corn, grains, grasses
Bean Weevil (Acanthoscelides obtectus)	1/8" brownish gray 	white larva 1/8" 	Chews bean fruits and cowpeas	Beans and cowpeas
Cinch Bug (Blissus leucopterus)	1/5" black with white wings 	vile odor when adults are crushed	Sucks juice from plants. Attacks leaves and plant base.	Corn, small grains, grasses, sudangrass, sorghums
Angoumois Grain Moth (Sitotroga cerealella)	½" grayish 	1/5" white with brown head 	Chews grain	Cereal, grain

Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Granary Weevil (Sitophilus granarius)	1/6" brown no wings 	1/6" white with brown head 	Chews grains	Cereal, grains
Grasshopper	$1\frac{1}{4}$" 	Several species various colors ←	Eats, chews foliage	All crops
Greenbug (Aphids) (Toxoptera GRAMINUM)	1/16" yellowish green 	←	Sucks plant juice	Small grains, corn, grasses
Hessian Fly (Phytophaga destructor)	1/8" mosquito-like 	1/8" white 	Sucks juice from plants causing lodging	Wheat, barley, rye, grasses

Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Leafhopper	1/8" pale green 	←	Sucks juices causes hopper burns	General plant feeder
Corn Billbug	½" reddish brown and black 	½" white grub with white head 	Adult chews foliage, larvae feed on roots	Corn, small grain, rice
European Corn Borer (*Pyrausta nubilalis*)	yellowish-brown moth 1" 	1" flesh color 	Larva chews into stalks and ears, causes lodging	Corn, sorghum, sudangrass
Corn Earworm (*Heliothis armigera*)	1½" yellowish green or gray 	1½" varies from green to black 	Chews corn ears, tobacco, buds and cotton bolls	Corn, tobacco, cotton, tomato

Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Corn Root Aphid (Anuraphis maidiradicis)	1/10" 	1/10" ←	Sucks juice from roots	Corn, cotton, grasses, weeds
Southern Corn Rootworm (Diabrotica undecim-punctata howardi)	½" yellowish green 	½" yellowish white 	Chews into stem and feeds on roots	Corn, small grain, grasses, cucumbers
Cotton Boll Weevil (Anthonomus grandis)	¼" snout beetle yellowish black 	½" white with brown head 	Chews cotton bolls	Cotton
Lygus Bug	¼" pale green to yellowish brown 	←	Sucks sap blasts floral buds	Alfalfa, cotton, beans, sugar beets

Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Sweet Clover Weevil	¼" dark gray 	½" grayish-white 	Chews stems, buds, leaves (crescent-shape)	Sweet clover
Wheat Jointworm (Harmolita tritici)	1/8" wasp-like 	1/6" yellowish-white 	Chews on stem near node (causes knots and weak stem)	Wheat
Wheat Stem Sawfly (Cephus cinctus)	3/8" wasp-like black 	½" yellowish-white, brown head 	Chews upper stems	Small grains, grasses
White Grub (Phyllophaga crinita)	1" brown 	1" white 	Grub chews roots, beetle chews tree foliage	Corn, grasses, grains, oak tree

Insect	Diagram of Adult Size and Color	Damaging Stage Size and Color	Eating Habits	Crops Attacked
Wire Worm	½" brown 	1½" yellowish brown 	Chews seed and stem below ground	Corn, small grains, grasses

84

UNIT IV - CEREAL CROPS

A. INTRODUCTION

Cereals are crop plants belonging to the grass family which are grown for their edible starchy seeds. Included in these are rice, maize, rye, barley, oats, grain sorghums, millet and wheat.

Approximately one-half of the planted land of the world is devoted to cereals. They are the most economical source of concentrated carbohydrates for man and beast. A large part of the world population subsists mainly on either wheat, rice, or maize. As a nation develops, consumption of wheat generally increases.

Climatic conditions determine where each of the cereals can be grown economically. Cool season cereals are wheat, rye, barley, and oats. Warm season cereals are maize, rice, sorghum, and millet.

Wheat is generally grown in areas where the annual precipitation is between 15 - 45 inches. In India, it is grown in areas having 60 inches of rain per year, most of which falls when the crop is not growing. It is possible to grow cereals in drier areas with the use of summer fallow or supplemental irrigation.

All cereal production requires a frost-free period for a minimum of 90 - 100 days. Freezing will damage all cereals during heading, pollination, and early grain production. Wheat, barley, oats, and rye are capable of germinating and making their early growth under cool moist conditions. Spring grain varieties are planted as early in the spring as it is possible to prepare a seedbed. In areas with mild winters, they may be fall planted. Winter varieties are fall planted in temperate zones.

Rainfall pattern and high humidity during the growing season limits the types and varieties of cereals which can be grown in any area. Prevalence of disease, lodging and breaking of weak straws, difficulty in preparation of seed-bed and harvesting, are the chief hazards of producing small grains in areas of high rainfall. Climate at harvest time is a very important consideration. Crops should generally be matured, harvested, and put into storage during relatively dry weather.

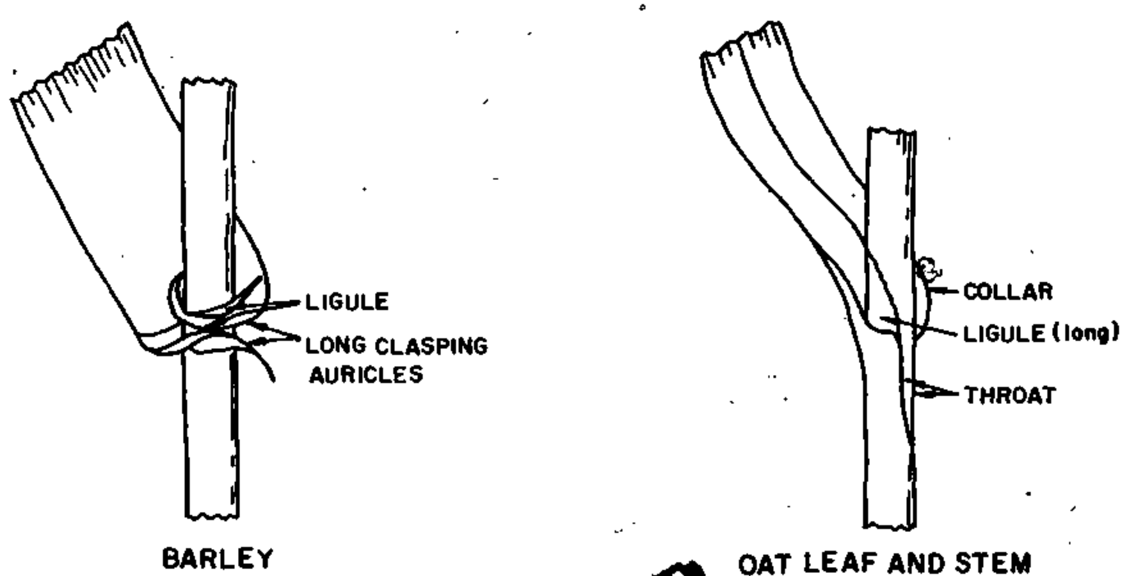
Cereals will play a key role in attempts to meet future world food requirements. Through variety improvement, disease control, pest control, improved cultural practices, extended irrigation, and improved fertilizer practices, the hazards of production will be decreased and yields will increase to help combat starvation.

Table 4 and Figure 50 illustrate the key identifying features of the small grains.

TABLE 4

IDENTIFICATION OF COMMON CEREAL GRAINS BY INFLORESCENCE

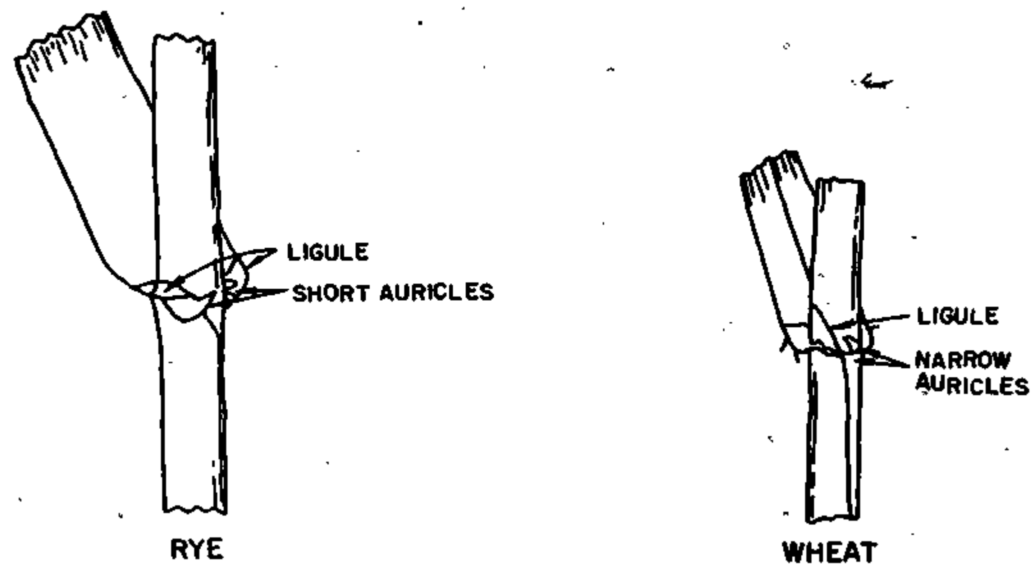
CROP	Type Inflorescence	Spikelets per node	Florets per Spikelet	Lemma	Glume	Mode of Threshing
Wheat	Spike	one	3-5 usual fert. on sterile	keel not barbed		threshes free
Rye	Spike		3 usual 2 fert. - 1 sterile	keel barbed		free
Barley	Spike	three	one	5 nerves	small hair-like	enclosed in hull
Oats	Panicle	one	3-5 usual 2 or 3 fertile	- - -	large papery	enclosed in hull
Rice	Panicle	one	one	5 nerves	small bristles	enclosed



SIDE VIEW OF GRAIN COLLAR REGIONS

Figure 50

Continuation of Figure 50



SIDE VIEW OF GRAIN COLLAR REGIONS

Figure 50

B. RICE

Rice is the principal food of approximately half the people in the world. Approximately one percent is produced in the United States. Rice is consumed at the rate of 200 to 400 pounds per person per year by many of the inhabitants of the Orient. In the United States, the average consumption is only about six pounds per year. In normal times, the United States exports rice.

Rice is believed to have originated somewhere in India or Indochina. The rice plant is a member of the grass family, is classified as Oryza sativa L., and is normally self-pollinated although some natural crossing does occur. It is an annual grass growing two to six feet tall.

Rice possesses many of the characteristics common to the other cereals. It differs principally in that it is grown on land that is submerged for 60 to 90 days. It thrives best under swampy conditions. The rice plant is able to transport oxygen from the leaves to the submerged roots where oxygen is released during photosynthesis.

The principal factors limiting rice production to rather definit regions of the world are favorable temperatures, a constant supply of fresh water for irrigation, and suitable soils. Rice can be grown successfully only in regions having a mean temperature of approximately 70° F or above during the entire growing season of four to six months. Soils should be fairly level and capable of holding water without too much seepage. Surface drainage is essential so the water can be removed readily to permit harvesting. From 36 to 60 inches of water is required to produce a crop of rice on suitable land.

Rice is grown on all types of soils, but soils of rather heavy texture underlain by an impervious subsoil at 1.5 to 5.0 feet below the surface require less irrigation. The loss of water by seepage is small through these soils and is the chief reason for selecting such soils. The land on which rice is grown is normally submerged from four to eight inches deep from the time of seeding until just before harvest.

Commercial fertilizers are widely used for rice production. Nitrogen gives the best response on most soils and is usually applied in the form of ammonium sulfate or urea. Some soils require a complete fertilizer. Amounts of these minerals to be supplied will depend on local conditions. In some cases, the growing of a leguminous green manure crop has proved beneficial.

Roots

The roots of rice are fibrous and consist of rootlets and root hairs. The depth to which these roots extend varies from six to eighteen inches. The rice seedling has one seminal root, but adventitious roots arise from the first three nodes.

Stems

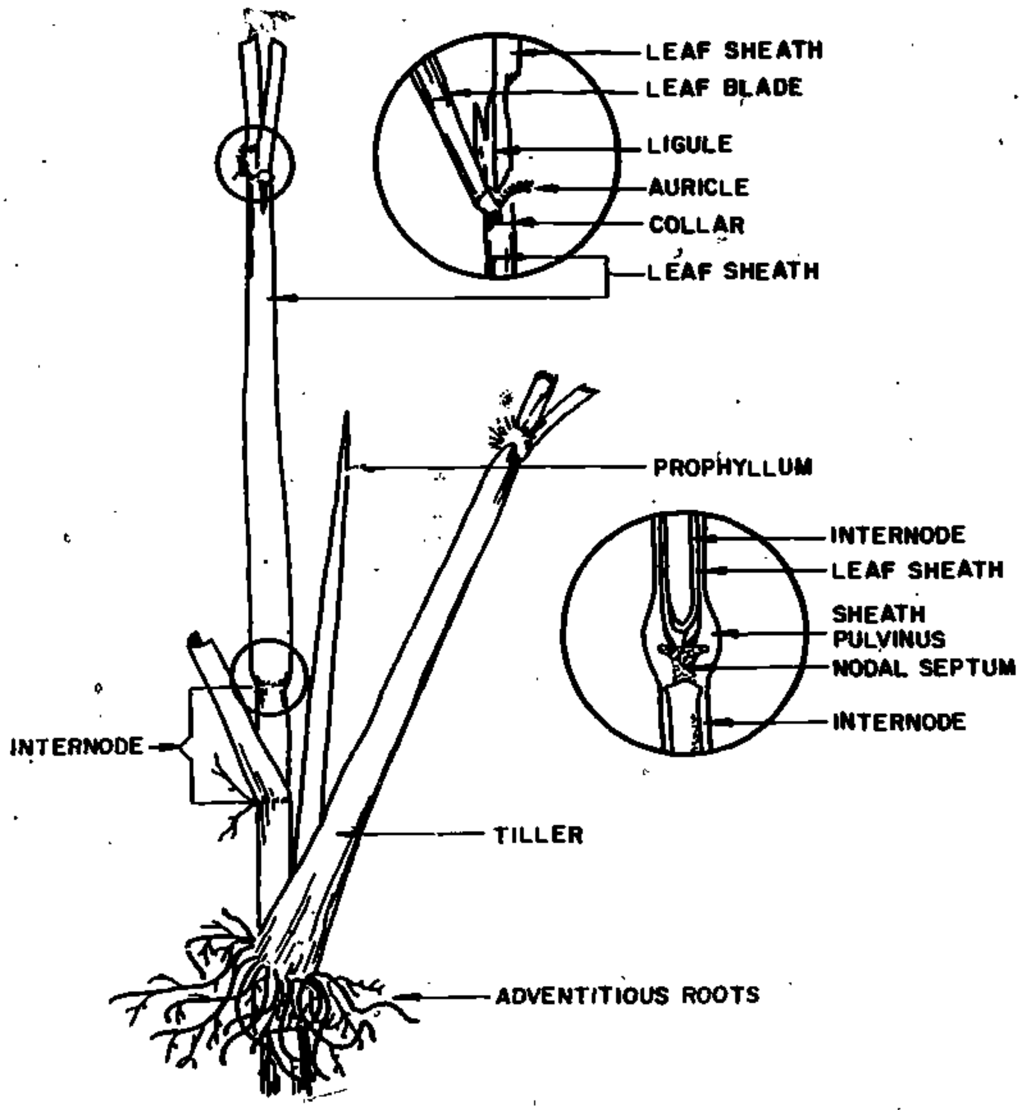
Stems or culms of the rice usually grow to a height of two to four feet. Rice generally tillers freely (Figure 51) but also has a tendency to branch at the nodes. This occurs with early maturity and low population rates per acre. Excessive branching, however, would increase lodging and make harvesting more difficult as well as lowering the quality.

Varieties that have strong culms, regardless of size, do not lodge so readily. If the leaf sheaths grip the culm rather tightly, the stems are less likely to lodge.

Leaves

The leaves of the rice plant are borne at an angle on the culm, one at each node. The leaf sheaths are generally open and the ligule is longer than in other cereals. The color of the leaf sheath has been used in classifying rice varieties in certain areas of India.

Oxygen is transported from the leaves to the plant roots, therefore, care should be taken that excessive defoliation does not take place.



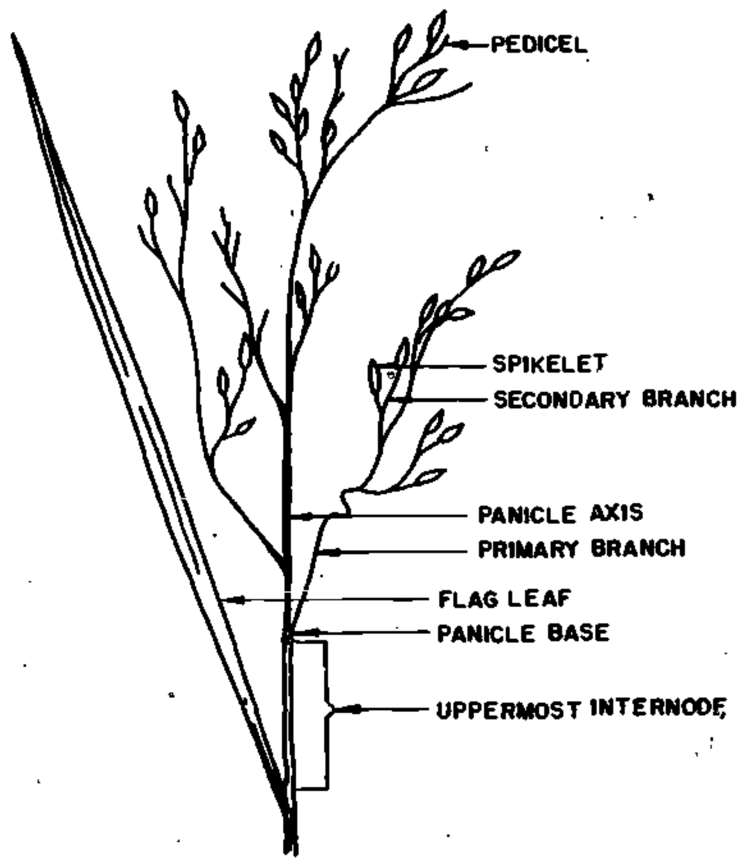
PARTS OF A PRIMARY TILLER AND ITS SECONDARY TILLER

Figure 51

Inflorescence

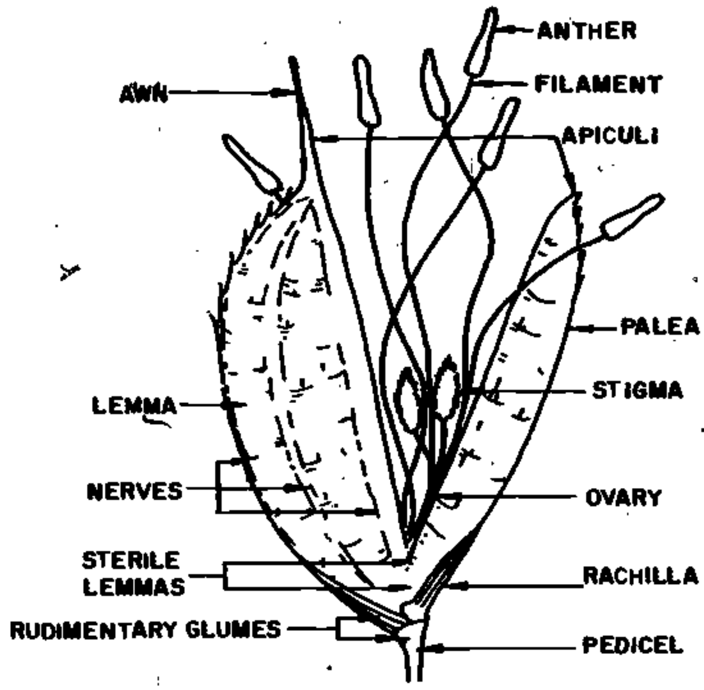
The rice inflorescence is a loose terminal panicle (Figure 52) of perfect flowers characterized by one-flowered spikelets (Figure 53). The spikelets are laterally compressed. The flower contains six functioning stamens which distinguish it from the other common cereals.

When blooming, rice flowers open rapidly and the anthers dehisce or burst when the flower opens, or, on rare occasions, before opening. The flowers may remain open twenty minutes to three hours. Flowers begin to bloom early in the day when temperatures are high, but slows down with cloudy and cool temperatures. Depending upon the variety, rice is normally self-pollinated with up to three to four percent natural crossing occurring.



COMPONENT PARTS OF A PANICLE

Figure 52



PARTS OF A SPIKELET

Figure 53

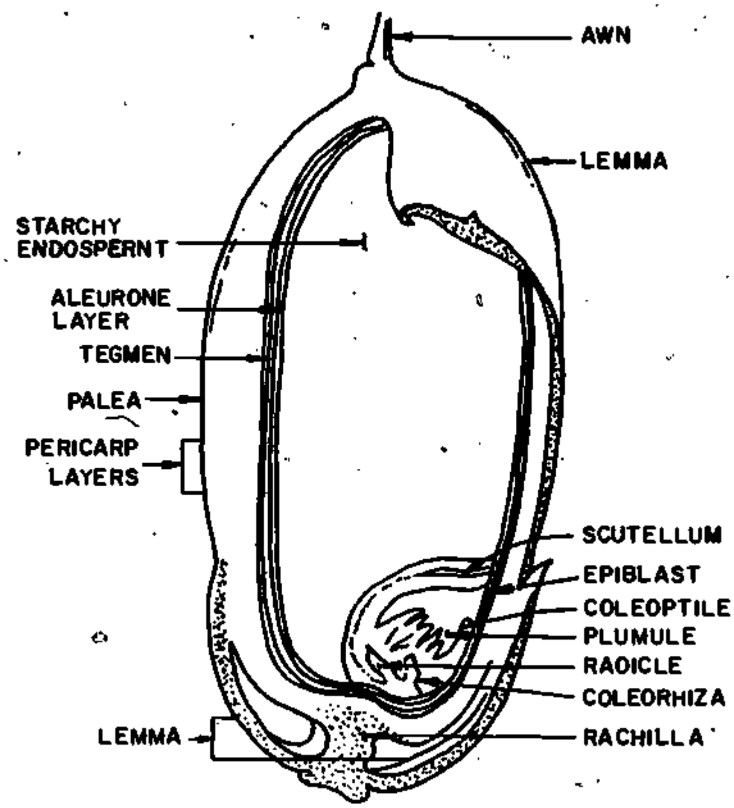
Seeds and Germination

The seed or kernel of rice is borne enclosed in the lemma and palea. These structures are commonly called the hull as shown in Figure 54. The hull will, in most cases, remain attached to the seed during the harvesting process. The rice seed encl sed in the hull is often known as "paddy" or "rough" rice. Rice with the ull removed is known as "brown" or "husked" rice.

Rice grains are of various textures, colors, sizes, and shapes. Some rice varieties possess semi-transparent kernels; others possess starchy grains while in others, the kernels may be colored. Rice grains having little or no color are usually preferred.

The two major groups of cultivated rice are Indica (long grain), grown in the tropical zones and Japonica (short and medium grain), which is confined to the more northern subtropical regions.

Seed that is to be used for planting should be free of weed seeds, have a high germination percentage, plump with a high weight per bushel, and should be of a known recommended variety.

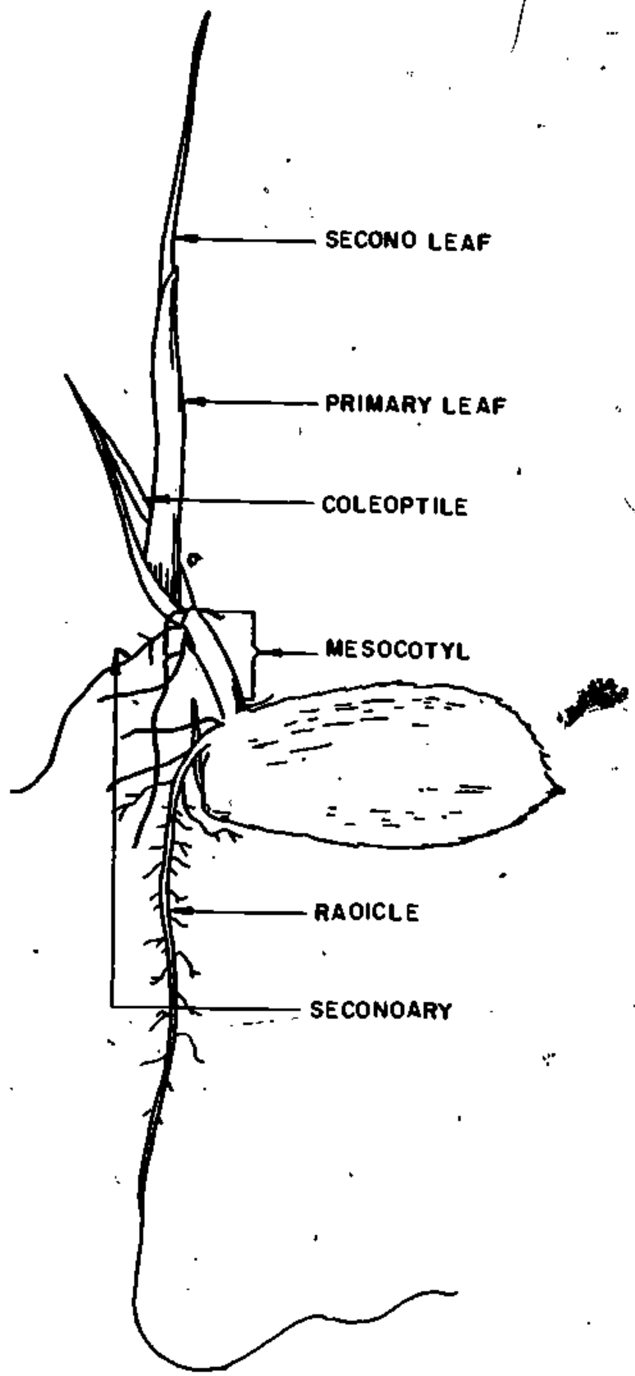


STRUCTURE OF A GRAIN

Figure 54

Rice can be planted directly in the field or started in a nursery and the seedlings later transplanted to the field. The parts of a germinating seedling are shown in Figure 55. The reasons for hand transplanting include a better utilization of the land by growing two crops a year, saving irrigation water, and better weed control. The seed is sown in small beds while the fields are occupied by other crops. When the seedlings are 30 - 50 days old, they are transplanted into fields or paddies that have been stirred [illegible] thin soupy mud into which three or four seedlings can be easily pushed. There seems to be no advantage in yield by transplanting as compared to direct seeding. Transplanting does have the disadvantage of requiring extra labor which is slow and laborious.

Seedbed preparation for lowland rice is done by plowing, usually to a depth of four to six inches, then harrowing and leveling between the levees. To reduce the growth of scum forming algae all old weeds, stubble and cover crops should be well turned under.



PARTS OF A GERMINATING SEEDLING

Figure 56

A field should be well leveled. Unless clods are worked, they will stick up above the general level of the field providing a platform from which weeds can emerge from the water. If the clods are too large, the seeds tend to be buried too deep when the irrigation water dissolves the clods.

When seeded direct, several methods can be employed. It can be drilled if the seedbed can be dried out sufficiently, or it can be broadcast.

Broadcasting may be done in two ways. The seed can be broadcast on a dry field. The field is usually dragged with a board, harrow, or similar tool to partially cover the seed. The field may be immediately flooded. This will cut down on weed growth and also help to settle the soil around the seed. Using the second method, the seed may be broadcast directly into the water after the field has been flooded to enable the rice to compete efficiently with soil organisms for available oxygen and with weeds for available space and nutrients.

To insure prompt submergence, the seed is usually soaked for 24 hours. Seed rice will soak up a maximum amount of water in 18 - 24 hours. It should be drained for about 40 - 48 hours. At the end of the soaking and draining period, the seed germs should be expanding and perhaps showing through the seed coat. Care should be taken that the seed is planted before the sprout has emerged to the point where it might be broken off. Sometimes the excess water is drained off the field after seeding and the seeds are covered with a thin film of mud. Germination of the presoaked seed is rapid. As soon as the seedlings emerge, a shallow flood of water is added to fields that were drained after sowing.

Under normal conditions, 125 to 150 pounds are usually sown broadcast. Yields do not seem to be much different if the rate varies from 125 to 200 pounds per acre. Heavier rates are better on old land where tillering is limited. Lighter rates yield well on new fertile land. Extremely thick stands lodge more readily, but a thick stand matures and heads more uniformly than a thin stand with abundant tillers. Eight to ten plants per square foot is considered a good stand.

Irrigation

Once established, fields should be under an average measured depth of six to eight inches of water continuously for effective weed control. Rice can emerge from this amount of water in 18 to 25 days. Lowering the water to less than six inches, even for only a few days, can greatly intensify the weed problem.

Water provides a blanket which will protect young seedlings against low early morning temperatures. Water should be reasonably warm before it is applied to the field.

Occasionally, water is low in oxygen and retards growth. Any type of agitation before the water reaches the field helps to increase the oxygen content. Usually one or two checks in the irrigation stream will insure that the water has absorbed enough.

After flooding, the water required to maintain a constant depth in the field will equal the sum of losses due to transpiration by plants, evaporation from the water surface, deep percolation and spillage. These losses will vary, but total seasonal use will normally vary from five to nine acre feet of water. On deep, permeable soils, the irrigation water requirement may be two to three times this amount. A rate of flow equal to one cubic foot per second (450 gallons per minute) for each 50 acres being irrigated is usually required to maintain water levels on the fields.

Draining of the fields at the proper time before harvest is necessary to dry the soil enough to support harvesting equipment. It is equally important to hold the water on the land long enough to permit the rice to reach the proper stage of maturity.

A good estimate of when rice will be ready for harvest can be made by observing the date of first heading, when approximately one-tenth of the heads are emerged. Crops of average yield will be ready for harvest in approximately 45 to 50 days.

Drainage usually takes place when all the heads or panicles are turned down and ripening in the upper portions. This stage is reached about two weeks before full maturity.

Harvest

Rice, like other small grains, is ready for harvest when the seeds in the lower part of the panicle are in the hard dough stage. The crop may be cut with a binder or combine, as is done with other grains.

The crop is harvested by hand with a sickle over much of the world. This generally takes place when the moisture content is between 22 - 25 percent. The harvested crop, tied into small bundles, is allowed to lie in the field for two or three days, and is then taken to a threshing floor to separate the paddy from the straw. Occasionally, only the panicle is harvested leaving most of the straw in the field. Bullocks or flails are used then to separate the grain from the chaff. This is a slow and tedious process.

Stripping of the seed from the head is sometimes practiced. Some African farmers use a relatively large snail shell to accomplish this.

Rough rice or paddy must be dried down to thirteen to fifteen percent moisture before it can be stored for any period of time. When milled, rice generally yields about 70 percent of whole and broken kernels, seven percent of bran, three percent of polish, and twenty percent of hulls.

In the process of milling, all of the bran coat is also removed and the kernel polished to leave nothing but the starchy endosperm. In certain Asiatic countries, especially in India, Burma, and Ceylon, much of the rice is parboiled before milling. Parboiling consists of soaking and steaming the rough rice until the endosperm starch is gelatinized, and then drying and milling the grain. The advantages of parboiled (commonly called converted) rice are that it is less apt to break during the milling process, the rice remains whole during cooking, the rice keeps better, and more of the water soluble vitamins are preserved in the kernel.

Whole kernel, well polished rice is used for food. Broken rice is used as a starchy adjunct in the brewing or distilling industry. The light brown powder removed during the polishing process is used for feed for livestock and poultry.

C. WHEAT

Historically, wheat has been an important cereal grain for over 6,000 years. At the present time, wheat is the most important food for man on a worldwide basis, with the possible exception of rice. In the United States, wheat is the number one food crop and is second only to corn as the most important livestock feed crop. It is preferred to any grain for human food.

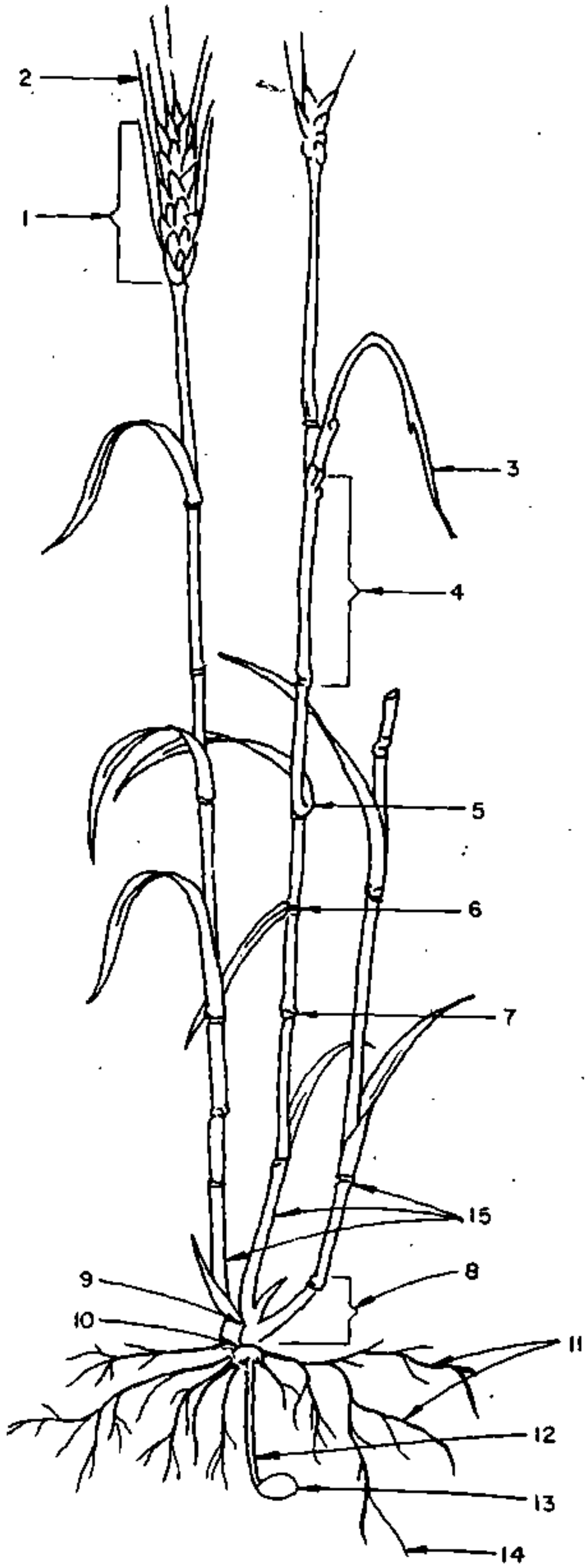
The origin of cultivated wheat is lost in antiquity. It is believed to have originated in southwestern Asia.

Wheat is poorly adapted to either warm or moist climates. It requires a comparatively cool dry season which favors plant growth and retards parasitic diseases. High rainfall, especially when accompanied by high temperatures, is unfavorable for wheat.

Most of the wheat is produced on fertile soils that formerly were prairies. To produce wheat of high protein content, it is necessary that the soil be well supplied with nitrogen. The addition of organic matter to the soils has proven to be very beneficial except in those areas of limited rainfall. Many of the wheat soils respond to applications of phosphorous fertilizers.

Classification

Wheat belongs to the grass family and the genus Triticum. Although as many as eighteen species of wheat have been described, only a few are



Name of numbered structures

1. Spike
2. Awn or beard
3. Leaf blade
4. Leaf sheath
5. Auricle
6. Ligule
7. Node
8. Internode
9. Coleoptile
10. Crown
11. Secondary root system
12. Mesocotyle (subcrown internode)
13. Remains of seed
14. Primary roots
15. Culms, stems or tillers

GROSS MORPHOLOGY OF WHEAT PLANT

Figure 56

important. The chief of these are the common bread wheat (Triticum Vulgare), the club wheats (Triticum Compactum) and the durum wheats (Triticum Durum). Each of these species has distinct characteristics and qualities that make it suitable for special uses. The club wheats are soft and are used for pastries; the durums are hard and are used for macaroni; and the common wheats are more or less intermediate and are especially useful for bread.

Wheat is classified as an annual because it completes its cycle of growth within one crop season. However, a large part of the wheat produced in the world must be classified as a winter annual - a plant that is seeded in the late summer and fall, passes through the winter in a dormant state, and completes its cycle of growth the following year. In regions where the winters are very mild, typical spring varieties may be grown as winter annuals. The gross morphology of a wheat plant is shown in Figure 56.

Roots

The wheat plant has a fibrous root system. The seminal or primary roots develop when the seed germinates growing downward from the lower end of the embryo. After the young plant emerges from the soil and unfolds a few leaves, the coronal or permanent roots arise about one inch below the soil surface, regardless at what depth the seed may have been planted.

Wheat roots may elongate as much as one-half inch per day. Roots of a single wheat plant may have a spread of four feet in width and penetrate three to six feet in depth. The bulk of the roots will be in the one to three foot zone. Wheat roots will not penetrate into soils that are either continuously dry or waterlogged. The root hairs primarily absorb water and mineral nutrients necessary for plant growth.

Stems

After a wheat seed germinates, the short internodes elongate into the first young culm or stem. The lower internodes which are formed first are very short. Stem elongation continues by cell division as well as cell elongation. Although there are a few "solid stem" varieties, wheat, in general. has hollow internodes.

When a cereal breaks over during the growing season due to rain, wind, or sheer weight of maturing grain, it is said to be lodged. Factors contributing to lodging are:

1. Weak root system
2. Weak straw
3. Length of straw
4. Leaf area

5. Low dry matter per unit length of stem
6. Excessive fertilization
7. Insect pests

Lodging usually results in reduced yields due to interference with the conducting tissues located in the stem.

The stem of a cereal plant is divided into nodes and internodes. The length of the internode varies with the position in the stem and by variety. The spike or inflorescence is borne on the uppermost internode.

In addition to the main stem, branches known as tillers may arise from each of the subterranean nodes in most cereals. In wheat, five to more than fifty tillers may arise from a single seed, depending on favorable environmental conditions and plant population (seeding rate). Each tiller develops its own root system.

Leaves

Leaves of wheat arise from buds on the plant stem; specifically the node. Made up of two parts - the sheath and the blade - they are flat, tapering to a point, and are parallel-veined. Leaves play a key role in photosynthesis and transpiration.

Defoliation of wheat during active growth reduces the photosynthetic area of the plant and may result in serious yield reduction. Grazing, hale, injury, and leaf diseases are the principal causes of leaf loss. High temperature, low humidity and wind movement favor increased transpiration. It takes approximately 550 pounds of water to produce one pound of dry matter in wheat.

Inflorescence

The inflorescence of wheat is called a spike. This is borne on the uppermost node of each stem. The individual flowers called spikelets are attached directly to the central stem or rachis of the spike.

The spikelets consist of one or more florets, each surrounded by two structures called glumes. In each floret are the three stamens, the pistil, and the lodicules. Wheat is self-pollinated, showing less than 0.5 percent cross-pollination. The fruit of the wheat plant is one seeded, dry, and commonly known as a caryopsis, grain, kernel, or seed. The kernel consists of a pericarp (outer covering), endosperm and embryo. The seed is matured when it is down to approximately 35 percent moisture. It is usually harvested and stored at fourteen percent or less moisture. If stored under cool, dry conditions, wheat seed will remain viable up to 30 years. A wheat kernel is made up of approximately thirteen to fourteen percent bran, two to three percent germ, and 83 - 84 percent endosperm.

Wheat seed must take up water to reach a moisture content of about 30 percent before germination will take place. The processes of conversion of the seed starches to sugars, respiration and growth begin as the seed first takes up water and swells. An oxygen supply, adequate moisture and a temperature of 40 - 60° F are necessary for germination.

Cultural practices

1. Plant plump seed treated with a fungicide. Seed treatment is very important to control some seed borne diseases.

2. Plant seed about one to one and one-half inches deep if good moisture is available. Plant into moisture, but never deeper than five inches. Plant so that the crop grows in cool weather and matures as the days get long and warm.

3. Fertilizer should be applied. Follow local recommendations relative to timing and amount of N, P, and K. Banding the fertilizer one and one-half inches to the side and one inch below the seed has given good results.

4. Weeds can be controlled chemically or by hand; 2, 4-D can be applied with sprayers to control broad-leaf weeds. Use about three-fourths pound of actual 2,4-D per acre in as much water as needed. This should be applied when the wheat plants are approximately six inches high.

5. Irrigation. Critical periods during which the soil should be up to field capacity in the root zone include; germination stage, tillering stage, the boot stage, and early seed filling stage.

6. Keep a close watch for insect pests on growing and stored grains.

7. Wheat can be safely stored at fourteen percent moisture or less.

Harvest should start when the grain is ripe. It takes about 40 - 50 days from heading to the time the grain will be ready for harvest and storage.

D. CORN

Corn, commonly called maize, has been cultivated throughout the world for several thousand years. At the time of the discovery of the New World, corn was already being cultivated in many parts of the American continent. Its value as a food crop was soon recognized, so that it soon spread over large areas of Europe. The Portugese brought maize to the West Coast of Africa at the beginning of the sixteenth century and a little later to India and China.

Corn, or maize, played an important part in the development of the Mid-Western United States. By 1850, there was a distinct corn and livestock belt in the United States. Corn yields, however, remained the same until about the 1930's, at which time hybrid corn became available.

Corn is the third most important cereal in the world after rice and wheat in production and acreage. It is an important crop in the warm temperate regions as well as in the humid subtropical zones. It is also grown successfully in the tropics. It is grown to a certain extent in all States of the Union.

In many parts of the world, maize is the most important foodstuff. In particular, it provides the daily bread for the indigenous population of poorer rural areas. Because of sole dependence on maize for eating purposes, certain nutritional deficiencies have arisen. Food and feed account for 80 - 95 percent of the total amount grown. Seed and industrial uses make up for the rest.

Corn is a grass and belongs to the family Gramineae, genus Zea. Seven types of corn grown are: pod corn, flour corn, flint, dent, sweet corn, popcorn, and waxy corn.

Nearly all of the corn grown in the United States at the present time is dent corn. Dent corn is characterized by a depression or "dent" in the crown of the seed. Rapid drying and shrinkage of the soft starch results in the characteristic denting.

Flint corn is predominant in the agriculture of Europe, Asia, Central and South America and in Africa. In general, the seeds of flint maize are hard and smooth and contain little soft starch. Flint corn is usually earlier in maturity, germinates better, tillers more than dent and is generally more drought resistant. Normally, the seeds are smaller than dent corn.

Sweet corn is grown primarily in the United States. This type of maize contains such a large proportion of sugar to starch that the kernels are wrinkled and translucent when dry. The ears are usually picked green for table use.

Soft or flour corn has been widely grown in the drier sections of the United States and in some areas in South America and South Africa. Flour corn is somewhat similar to flint corn in plant and ear characteristics.

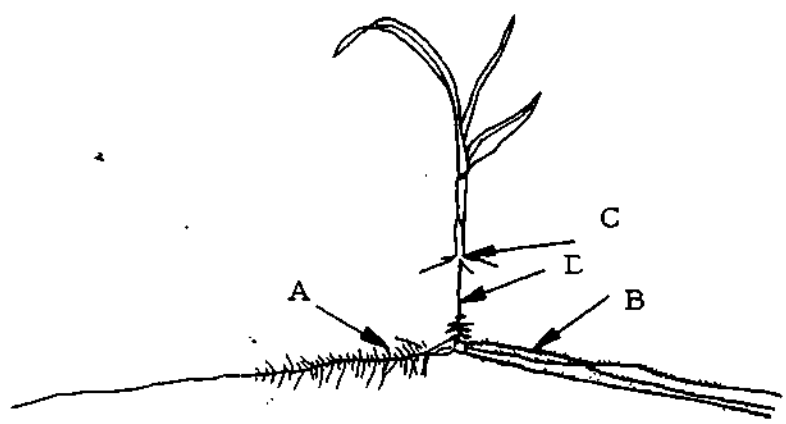
Popcorn is almost entirely restricted to the United States and Central America. The kernels are usually small and contain an even higher percentage of hard starch than flint maize. It bursts on the expansion of moisture into steam in the internal soft starch.

Waxy corn is rather limited in the amount and areas grown. In this type of maize, the starch molecule differs considerably from other types. It is gummy and has some characteristics of tapioca starch.

Pod corn is so named because of the unusual type of kernel, each of which is enclosed in a pod or husk. The ear is also enclosed in husks. It is not grown commercially.

Roots

As with all gramineae, the root system contains no tap root, and its feathery strands spread out in all directions, mainly in the top soil. In most varieties, the form of the root system shown in Figure 57 is characteristic.



Corn plant two weeks after planting: (A) Primary seminal root, (B) lateral seminal roots, (C) coronal or crown roots, and (D) subcrown internode.

ROOT SYSTEM OF CORN

Figure 57

The three to five seminal roots may persist throughout the life of the plant. The main adventitious fibrous system, the crown or coronal roots developed from the lower nodes of the stem below ground level, spread out in a lateral direction in the upper layers of the soil, then turn vertically downwards and tap the lower levels of the soil. Brace roots arise from the nodes above ground. but function as crown roots once they have entered the soil.

The extent to which the roots penetrate to the deeper layers depends largely upon the supply of nutrients and on the drainage of the soil. In soil which is rich in nutrients, the roots are comparatively strong and branch out in all directions. In dry soil they grow longer and individual roots penetrate up to eight to twelve feet.

Stem and Leaves.

The stem culm, or stalk, is normally six to nine feet high. Individual quick-ripening varieties mature at a height of only two feet while some tropical varieties can reach a height of 20 - 22 feet. The stem averages about one to one and one-half inches thick and normally possesses about fourteen internodes. They are solid stemmed.

The number of leaves average between twelve and eighteen. They vary between two and four feet long and can be up to four to five inches wide. They have parallel veins. Most maize is normally single stemmed. In some types of maize, one finds all types - single stemmed and single cobbed to bushy forms.

Flowers and Pollination

Like all other cereal grains, the corn plant bears its flowers in spikelets, the characteristic units of the inflorescences of all grasses. The plant is monoecious. The spikelets are of two types, male and female, the male being collected into a male inflorescence or "tassel" which is carried terminally on the main axis. The male spikelets can be easily recognized before flowering, just as the tassel emerges from the leaves at the top of the plant. The male inflorescence is a fairly compact, many branched panicle varying in size with variety.

The female inflorescence is known as the "cob" or the "ear". It consists of a modified lateral branch arising from an axillary bud of the main stem. The ovary itself is surmounted by a long style, the silk, which grows rapidly and emerges from the top of the husk. It is receptive to pollen along most of its length.

Pollination occurs by means of wind and gravity. Any movement of the plant helps to shake out the pollen, and it is usually dispersed within a few hours. Pollen is produced in extraordinary quantities from the opening flowers of the tassel. The silks are receptive almost as soon as they emerge. When the pollen grains fall on the moist surface of the silk or style, they adhere and the moisture induces germination and ultimate fertilization. After fertilization has been accomplished, the silks wither away and the grains develop. The grains are born in pairs on several longitudinal rows along the length of the cob. Individual ears may have from four to thirty or more rows of grain. The number of rows on an ear is determined partly by heredity, but may also be affected by environment.

The grains are surrounded on the cob by the chaffy remains of the glumes and the lemmas and paleas of the two flowers. Usually a maize cob contains between 300 and 1,000 seeds. The seeds are rounded or dented depending on variety. The color also varies greatly with variety, ranging from white to yellow, red and purple, to almost black. The anatomy of the corn kernel is not too much different from that of other cereal crops.

Cultural Requirements

Corn is a warm season annual adapted to areas where both day and night temperatures are over 70° F during much of the growing season. At all stages, the corn plant is killed by very slight frosts. Relatively high temperatures are required for germination. At low temperatures, seedling growth is so slow that fungi readily invade and often destroy the embryo.

Corn demands a constant supply of moisture. In areas where drought is of frequent occurrence, corn is replaced by sorghums, wheat, or millet. On the other hand, corn will not tolerate poorly drained soils and is very sensitive to acid and saline conditions. It is a poor competitor with weeds and is almost always grown as a row crop. Where soil is favorable and moisture abundant, corn will tolerate very high temperatures and is one of the highest yielding crops known.

It is grown on a wide variety of soils but performs best on well drained, aerated, deep, warm loams and silt loams containing an abundance of organic matter and well supplied with available nutrients.

Since the maize crop leaves much of the ground uncovered, soil erosion and water losses can be severe. Special precautions for runoff control are important. Examples include contour plowing, strip cropping, and terracing of the steeper slopes.

Depth of planting is largely dependent on climate, moisture conditions and soil. Seed will emerge from as deep as eight inches, but deep planting has a retarding effect on germination. In general, the larger the seed, the deeper it may be planted. It should be brought out that no matter what depth the seed is planted, the crown roots are always formed at approximately the same depth below the surface of the soil. The final preparation of plowed land usually consists of pulverization of the surface four inches so as to provide a soil free from large air spaces in which to plant the seed.

Corn is usually planted in rows 36 to 44 inches apart either in a furrow or on level ground. Surface planted corn is often planted in hills or check rows so cross cultivation is possible for better weed control. When seed is drilled in the row, cultivation is possible in only one direction.

In some areas, corn is planted in "listed" rows or furrows. If moisture is limited, the seed is planted at the bottom of the furrow. If drainage is a problem, the seed is planted at the top of the ridge. Oxygen is then available to the roots.

With the typical spacings used for planting corn, the number of plants per acre range from 3,000 to 18,000. Corn can be planted thicker on fertile than on infertile soils. Moisture shortages necessitates thin rates of planting in spite of productive soils. Under semiarid conditions, the rate is adjusted to the limited moisture available. Planting rates of 25,000 to 30,000 plants per acre have shown increased yields with some of the new hybrid varieties where soil fertility and moisture are plentiful.

The principal reason for the cultivation of corn is to control weeds. Weeds draw moisture and plant food from the soil. Deep cultivation in which the roots of the corn plant are sometimes pruned is certainly not beneficial. Weeds should be controlled when quite small. A pre-emergence spray of the proper herbicide gives the corn plant a chance to become established and to partially shade the land, retarding future weed growth. The best time to control annual weeds is just before or right after emergence. As the corn increases in height, inter-row cultivation should be carried out at progressively shallower depths in order to minimize injury to the roots.

Irrigation

Well distributed rainfall in adequate amounts represents an ideal condition for maize production. Irrigated agriculture has developed most extensively in those areas of the world where moisture limits maize yields. When the moisture limitation is removed by irrigation, the use of fertilizers may become very effective. Soils receiving adequate fertilizers produce much greater yields per unit of irrigation water than do infertile soils.

Adequate water to prevent wilting of the maize plant is essential throughout the growing season for production of high yields. Certain growth periods, however, are extremely critical. The tasseling-to-silking stage is particularly important. If moisture is lacking during this time, pollination is incomplete and poorly filled ears result.

Another important point is to be sure to have the soil reservoir filled with water at planting time. This ensures adequate reserves of subsoil moisture from which the crop can draw.

Fertilization

Barnyard manure, when it is available, is commonly applied to land to be planted with corn. In areas where cattle manures are in short supplies, green manures can provide a valuable organic supplement. Composts and crop residues are also plowed under to help improve the tilth and organic matter content of the soil.

Although a whole range of elements are essential to plant growth, only N, P, K, and Ca are of major importance as fertilizer nutrients. This is because the other essential elements are generally required in small quantities or traces, and the soil is usually adequately supplied with them. Visual symptoms of nutrient deficiency only appear when the soil is already extremely impoverished in nutrients. Considerable reductions in yield may occur long before deficiency symptoms are apparent. Soil tests, plant tissue analysis, and several other tests help in determining fertilizer requirements of the soil for maximum yield.

Nitrogen is without question the most important fertilizer for corn. It is essential for the growth and reproduction of plants. Lack of nitrogen usually limits corn yields more than any other nutrient. The amount of N applied to the fields will vary from almost nil to more than 150 pounds in more intensively managed areas. Quite a large percentage of the corn crop receives some of its N fertilization as a side dressing or post emergence application. Nitrogen deficiency is characterized by reduced vigor, smaller leaves, a fairly uniform pale green or yellowish-green leaf color, and yellowing and drying along the leaf midribs in widening bands towards the tip.

In the corn plant, phosphorous principally affects the development and set of the grain. It also stimulates early root formation and growth and hastens crop maturity. Phosphorous exists in many different organic and inorganic form combinations, but only a small proportion of the total phosphorous in soil is available to plants. Applications up to 75 pounds of actual P_2O_5 are not uncommon to corn soils. Phosphorous deficiencies often causes stunted growth, delayed ripening, poor root development, purpling of the leaves, and an abnormally dark green leaf color.

Potash requirements of corn are fairly high. Although it is a vitally important element, its function is not fully understood. Potassium does not accumulate in the grain as does phosphorous. Consequently, the returning of crop residue to the soil after harvest greatly reduces the depletion of this element in the soil. Potassium deficiency results in a characteristic pattern of leaf discoloration by small whitish-yellow spots, followed by scorching or browning of the leaf edges.

Fertilizers should be applied in bands or local areas near the seed as the early root system is limited in extent, soil and air temperatures are often cool, and the soil is too moist for desirable aeration. All these factors reduce the plant's ability to absorb nutrients from the soil. To promote early growth, it is important in many areas to apply a "starter" fertilizer to supply a high concentration of nutrients in the zone where the roots are most active. Careful placement is important to avoid concentrating the fertilizer too near the seed. The fertilizer should be placed at or slightly below the level of the seed and one to two inches to the side of it.

Harvesting

About seven to eight weeks after flowering, the corn is physiologically mature and can be harvested. The percentage of moisture in the grain at harvest is perhaps the best criterion of maturity. Outwardly maturity can be recognized by the yellowing of the leaves. The husks of the ear become yellow, papery and dry, the grain hard and glossy.

Physiological maturity in corn occurs at about 35 to 40 percent moisture content in the grain. Very dry weather in the fall or an early frost may stop growth and lead to moisture levels lower than normal.

The harvesting of the corn plant is not so closely tied to maturity as with other cereals. As the kernels do not "shatter", the ears can be left on the stalk until the grain is quite dry.

On smaller farms, the ripe cobs are broken off the stalk by hand. The husks are turned back and the ears are tied together and hung up in the air to be dried down to fifteen percent water content. A "husking hook" or "shucking pin" greatly facilitates removal of the husk.

The work of husking corn by hand is being rapidly replaced by easier, faster mechanical methods. The corn plant must have certain characteristics before the machine can do an economical job. It must have a strong root system, it must not lodge, and the ear should be placed at a fairly uniform height with fairly open husks.

The grain can be shelled from the ear when tne mosture content is 25 percent or less, but the shelled grain cannot be stored safely in bins until it contains less than thirteen to fourteen percent moisture. Consequently, most corn is stored as ear corn until moisture content is lowered. The stored grain, both shelled and in the ear, should be watched closely for insect infestations. A periodic check, plus a periodic dusting with malathion, usually keeps the grain insect free.

A considerable amount of corn is harvested as silage. The most complete utilization of the plant is realized in this manner as it is cut when the kernels are in the full dent, hard dough, or glazed stage before serious loss of leaves occur. It makes a very good feed for livestock, especially dairy cattle. Silage is a moist feed that has been preserved by fermentation in the absence of air. The fodder is commonly chopped into small sections and stored in a silo, pit, or trench. Properly preserved silage will conserve a greater proportion of the nutritive value of the green plant.

The leaves and stalks of a corn plant usually contain about 30 percent of the total nutrients in the corn plant. Stover from corn, either husked or snapped, is usually utilized for pasture. The leaves are utilized by the livestock, but stalks generally are left to be subsequently plowed under.

Seed Selection

There are very few visual criteria that can be used for selection of corn seed because of its cross-pollination characteristic. However, in those areas where the old open-pollinated varieties are still being grown, the following points seem to help to maintain productivity.

1. Yield sometimes is associated with weight and length of ear. Ears with heavier cobs, fewer rows, and heavier kernels are usually more productive than the old standard show type.

2. Field selection of seed ears from standing stalks at approximately the average date of the first fall frost. Seed ears should be selected from healthy vigorous plants that have produced sound ears.

Hybrid corn

The development and utilization of hybrid maize represents one of the great advances of the twentieth century. Hybrid maize depends upon heterosis. This is a phenomenon in which the crossing of two stocks produces a hybrid which is superior in size, or general vigor than either of the parents. Corn hybrids are as specific in their adaptation to the soil and climate as open-pollinated varieties and will perform in a satisfactory manner only when grown under the conditions to which they are suited. The better recommended hybrids distributed for commercial production have given yield increases that range from 15 to 35 percent above open-pollinated varieties. Many hybrids are outstanding for their stalk strength and lodging resistance.

On poor soils open-pollinated varieties sometimes outyield available hybrids. Also, hybrids often make a relatively poor showing under dry conditions. Because of their extreme uniformity, hybrids which shed their pollen during a hot dry period may give very low yields whereas open-pollinated varieties, which are irregular in pollen shedding, may partly escape the adverse weather period and produce a better yield.

Methods of developing and producing corn hybrids consist essentially in:

1. Isolation by self-fertilization and selection of lines that breed more or less true for certain characters.

2. Determination of the inbred lines with best combining ability.

3. Utilization of these selfed lines in double cross hybrids.

Inbred lines are produced by self-pollination of plants selected from among open-pollinated varieties or hybrids. In self-pollinating or selfing, the pollen from the tassel is placed on the silks of the same plant under controlled conditions. This is done by first placing a bag over the tassel and the ear shoots before either extrude from the plant. The silks are generally trimmed so they will grow out as a uniform brush. One or two days later, when the pollen is shed, it is poured on the silks and the entire ear covered once more. The seed from the better selfed ears is planted in progeny rows. Self-pollinations are then made on several plants in each row, and selection is continued. The vigor of these selfed plants goes down with each successive generation of self-pollination. It also begins to reveal many undesired characteristics which can be eliminated, such as sterility, suckers, silkless ears, etc. After five to seven generations of repeated self-pollination and selection, the inbred lines breed relatively true for most plant characters.

Frequently, after several years of inbreeding, the lines are planted in a special crossing block with every fourth, third, or alternate row planted to an adapted variety to be used as a pollen parent. The tassels are removed from all of the inbred rows before they shed pollen so that all plants are pollinated by the one parent variety. This so-called top-crossed seed produced on each row is planted separately to determine which inbred lines have the best combining ability, i.e. are likely to produce the highest yields in subsequent crosses. The better lines are retained and inbred until uniform.

Small groups of the high combining lines are then intercrossed in all possible combinations. The number of possible single crosses is determined by the formula N(N-1)/2 in which N is the number of inbred lines. A total of 45 single crosses is obtainable from ten lines.

A single cross involves a cross of two inbred lines, for example - A x B. Single crosses of field corn are not often used commercially because the seed yield is low. The three-way cross is made from a single cross and an inbred, for instance, (A x B) x C. The double cross is a cross between two single crosses, for example - (A x B) x (C x D). The commercial field corn hybrids now in production are either double crosses or three-way crosses.

For commercial hybrid seed production, the single crosses or inbred lines are grown in alternate rows or groups of rows in isolated fields. In these crossing fields, all the seed rows (females) are detasseled before they shed any pollen. The male or pollen parent rows are not detasseled, and the ears are not gathered for seed.

Synthetic Varieties

Because of the high cost of hybrid corn seed and the fact that the seed must be purchased every year, synthetic corn varieties have been developed. The greater variability of a synthetic might permit more adjustment than a hybrid to variable growing conditions.

Synthetics are produced by combining three or more inbred lines with no control over the pollination. Because of variations in soil, climate, etc. the seed produced during one year might not be quite the same as that produced the following year. The yield, however, should show quite an advantage over the open-pollinated variety.

E. SORGHUMS

Sorghum is a relatively new crop in the United States, but has been grown in Africa and Asia for quite a few centuries. The plant originated in the Asian and African tropics. The ability of the plant to remain dormant but uninjured during long periods of drought and then to resume growth when moisture becomes available has caused it to be referred to as the "crop camel".

In general, sorgo (sweet sorghum) is grown for forage, silage, and syrup, while grain sorghum is grown for grain. Some varieties, called dual purpose, are grown either for forage or for grain.

Sorghums are grown most widely in the semiarid regions of the world. They are often used for the second crop in regions where double cropping is practiced. During the "second rains" when moisture is limited and often undependable, sorghums are often successfully grown.

The most favorable mean temperature for the growth of the plant is approximately 80° F. The minimum temperature for growth is 60° F. The sorghums are well adapted to regions of limited rainfall where the average annual precipitation is only 17 to 25 inches. Sorghum is also highly productive under irrigation. The plants remain practically dormant during periods of drought but resume growth as soon as moisture becomes available. As compared with corn of similar seasonal requirements, sorghum has more secondary roots and a smaller leaf area per plant. A waxy cuticle apparently retards drying, allowing the leaves and stalks to wilt and dry more slowly.

Sorghum is grown successfully on all types of soil. In moist seasons, it does quite well on heavy soils, but does reasonably well on sandy soils. The chief drawback of sorghum as compared with corn are lower yields of succeeding crops, greater uncertainty in getting a stand, the necessity of prompt harvesting, storage difficulties and the lower market value.

Sorghum, again, is an annual grass belonging to the Gramineae family. It is a coarse grass with solid stems two to fifteen or more feet in height. The stems, like corn, are grooved and nearly oval. Some varieties have a sweet, juicy pith. The stems, as well as the leaves, are covered with a waxy bloom. The leaves have a saw-toothed edge. Leaves arise at each node, the blades being smooth with a waxy surface. Buds at each node often give rise to axillary branches. Crown buds give rise to tillers. Each new culm arising from crown buds develops its own root system and a new series of crown buds, but remains attached to the old crown.

Although considered an annual and usually grown as such, sorghums can survive as a perennial where the temperature is mild and soil moisture is available. A culm dies after it has flowered and after all active buds at the culm and crown nodes have elongated into stems. Then its roots also die and decay. In the meantime, new culms have grown alongside the original stem. This process continues as long as conditions are favorable for vegetative reproduction.

The sorghum inflorescence is a loose to dense panicle, bearing paired spikelets. The spikelet attached directly to the branch is always fertile and perfect. The other is either only male or sterile. Some sorghums have seeds fully covered by the chaff even after being threshed, while others are partially exposed and thresh out completely free from the chaff. A well developed panicle may contain as many as 2,000 seeds. Sorghums are approximately 95 percent self-pollinated in the field, but they will cross quite readily with other varieties of sorghum.

Sorghum Groups

Sorghum may be readily classified into rather distinct groups. These can be classed as:

1. Sorgos
2. Grain sorghums
3. Broomcorn
4. Grass sorghums

Sorgos are characterized by abundant sweet juice in the stalks, which usually range five to ten feet in height. This type is usually grown principally for forage and for syrup extraction. A considerable quantity of this type is also grown for silage.

Grain sorghums, in general, have larger heads and shorter stalks, and produce more grain in proportion to total crop than do the sorgos. The seed threshes free from the glumes. They are usually grown for grain, and the stover is not normally utilized for pasture.

Broomcorn produces heads with fibrous seed branches, 12 to 36 inches long, that are used for making brooms. The stalks range from three to fourteen feet in height, are dry and of limited value for forage.

Grass sorghums have slender leaves and stalks, with loose heads. It is grown chiefly for supplemental pasture, but care needs to be exercised because of prussic acid poisoning. Small plants, young branches and tillers are high in prussic acid or hydrocyanic acid (HCN). It is usually safe after the plant is eighteen inches high. Frosted sorghums or sudan grass should not be fed until it has dried out. Sudan grass contains only about two-fifths as much prussic acid as many of the sorghums grown under the same conditions.

Dwarf and double dwarf grain sorghums have been developed making the sorghum crop quite well adapted to machine harvest.

Sorghum is generally considered to be hard on the soil. Sorghums follow most crops readily, but care should be exercised in the choice of a crop to follow sorghums. Some of the injurious aftereffects of sorghum can be explained by the persistence of the sorghum plant to keep growing until killed by frost. Sorghum, thus, depletes the soil moisture to a greater extent than other crops. Another reason put forth is that the action of cellulose decomposing organisms during the decay of the sorghum roots and stubble ties up the available nitrogen in the soil. This negative effect is very pronounced on the crop immediately following, but almost completely disappears in a year or two. It is least noticeable with legumes and most pronounced with cereals. The aftereffect of sorghums on irrigated land may be overcome with nitrogenous fertilizers such as barnyard manure, or by planting inoculated legumes.

Fertilizers

In most areas, any fertilizer that would benefit corn would also be beneficial to sorghums. In places where sorghums are grown, moisture is generally the limiting factor rather than fertility. Under irrigation, a complete fertilizer is usually beneficial.

Cultural Practices

A warm mellow seedbed is essential to good seed germination. Weed control before planting is desirable. Sorghums are usually planted in cultivated rows, 36 to 44 inches apart. The amount of seed to plant per acre for a given stand will depend upon the condition of the seedbed, seed viability, seed size, and weather conditions at seeding time. Seed germination tests should be watched quite closely. A large discrepancy in field emergence may be expected if the laboratory test is below 85 percent. Seed treatment should always be practiced. Populations from 15,000 to 25,000 plants per acre are common. Seed of sorghum is generally covered with one to two inches of soil.

The date of planting sorghums should be so arranged that germination and early growth will take place during the period of moderately high temperatures, and the blooming and filling at such a time as to avoid the highest temperatures. A safe rule in all localities is to plant not earlier than two weeks after the usual corn planting time. Planting earlier than necessary for safe maturity usually reduces plant growth. Early planting is often practiced to avoid conflicts with other crops at harvest time or to clear the land in time for seeding future crops.

Harvesting of the crop should take place as soon after maturity as possible to avoid losses from shattering, birds, animals, and insects. If machine harvested, the grain should be thirteen percent moisture or less unless provision is made for drying the grain. The heads may be hand harvested from the plant before shattering takes place and is allowed to dry before the grain is flailed or treaded from the head.

Insect damage is quite common to sorghum grains. Storage facilities should be closely watched and periodically treated to maintain insect free grain.

F. MISCELLANEOUS CEREALS - BARLEY, OATS, RYE, MILLETS

Barley

Barley is grown in all the temperate zones of the earth. Its range of adaptation is very wide. It is grown at higher elevations and under more heat and drought than any other cereal. Barley produces best under a well-drained loam. It is the most dependable crop under conditions of alkali, frost, or drought.

Barley belongs to the Gramineae family and to the Genus Hordeum. The vegetative portion of the barley plant is similar to the other cereal grasses except the auricles of a barley leaf are very conspicuous.

The inflorescence is a spike with a zig zag rachis (central axis). Three spikelets are born at each rachis node. The spikelets are single flowered. In a six-rowed barley, all three florets at a node are fertile, while in a two-rowed barley, only the central floret is fertile as illustrated in Figure 57.

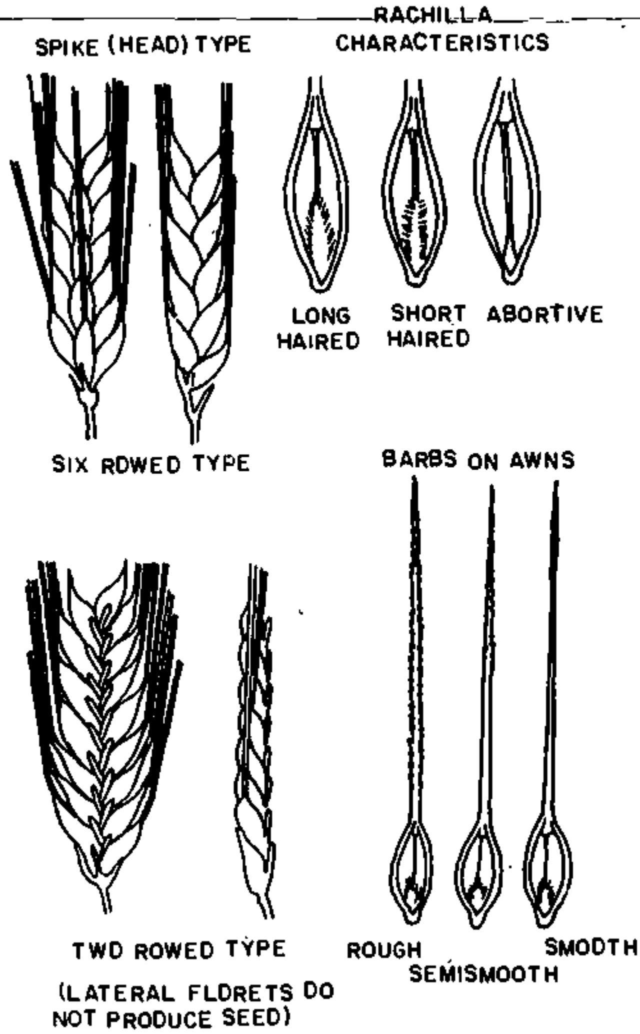
Except in hull-less varieties, the lemma and palea adhere to the caryopsis. The lemma may terminate in an awn or hood or it may be merely rounded or pointed. The awns of barley may be either rough or smooth. Awnless varieties are comparatively rare. Approximately ten to fifteen percent of the kernel consists of hull.

Barley is usually self-pollinated. This often occurs when the head is still in the boot (upper leaf sheath).

Cultural methods for barley are similar in most respects to wheat and oats. In general, barley makes its best growth after a cultivated crop. Most barley is seeded early in the spring, however, there are winter varieties that are fall planted. Longer growing periods favor greater yields. The seeding rate of barley is approximately six to ten pecks; the heavier rates being common in the more humid areas. Barley should be seeded at a depth at which moisture and air are available, or approximately one and one-half to two inches deep. It is planted with a grain drill in the United States, but is broadcast in other areas of the world.

Barley is generally harvested quite soon after is is physiologically ripe. If too much delay occurs, loss from shattering is considerable.

In the world over, barley is used for three purposes. Human food makes up only a small portion of this. It is used in soups as a whole grain, or is ground and used as a flour. Barley is a good animal feed and is almost equal to corn in food value. Another use for barley is as a malt for the manufacture of beer.



TYPES OF BARLEY

Figure 58

Oats

Oats are generally regarded as a crop of moist climates. It is true that as one progresses from the hot, humid, eastern United States toward the more arid west, oats gradually give way to wheat and then to barley. Oats have a poorer root system than either wheat or barley and are also more easily injured by hot weather at flowering time. They do relatively better upon moist, heavy soils than either wheat or barley. Progress in plant breeding, however, has made available varieties that greatly outperform the older varieties, which were mainly introductions from northern Europe. This has tended to increase the competitive ability of oats in recent years in the more arid regions.

Oats are later in maturity than wheat and not nearly so early as barley. For this reason, they do not have the ability to mature in short seasons as the other cereals and must be planted early. In general, oats do better than wheat or barley upon poor soils; similarly, they do not respond to highly fertile soil as well as barley or wheat.

As with other small grains, there are winter and spring varieties of oats. Winter oats, however, have little winter hardiness. As a result, few winter varieties of oats are grown north of the cotton belt. Winter barley is somewhat more hardy. Winter wheat and winter rye are still more hardy. There is a place for winter oats in the south, not only for grain, but for winter pasture, hay, and to provide cover for soil in the winter months. As with other cereals, the fall sown varieties outyield spring varieties by a substantial margin.

In California, as with wheat and barley, spring varieties of oats can be fall seeded because of the mild winters.

On the market, oats are classified on the basis of the color of the lemma and palea of the mature kernel. United States standards for grains establish five market classes for oats:

Class I	-	White Oats (includes yellow oats)
Class II	-	Red Oats
Class III	-	Gray Oats
Class IV	-	Black Oats
Class V	-	Mixed Oats

Four grades, plus sample grade based upon test weight per bushel, soundness, damage, foreign material, and percentage of wild oats are set up for each market class. Special grades indicate special quality or lack of quality.

In addition, a special market classification is established for feed oats. Feed oats are defined as "any grain which consists of either (a) 30 percent or more but less than 80 percent of cultivated oats, but not less than 65 percent of cultivated and wild oats combined, or (b) 80 percent or more of cultivated oats and not more than 10 percent of wild oats. Feed oats may contain not more than 25 percent of other grains, and may contain not more than 10 percent of foreign material of which 10 percent may include not more than 5 percent of fine seeds."

Botanically, there are about 50 species of oats in the world of which only two are of any great importance as cultivated plants in the United States. These two species are Avena sativa and Avena byzantina. Avena sativa includes most of the cultivated oat varieties. The red oats grown in the southeastern United States and other warmer areas belong to Avena byzantina. These species are fully fertile in hybrids. Many of the new improved oat varieties have been selected from hybrids between different varieties of the two species. Two wild oat species, A. fatua and A. barbata, are troublesome weeds on cultivated lands, but are valuable annual species on range lands.

Excessive rates of planting are likely to lead to severe lodging. When grown for grain under low himidities, oats shatter badly. This problem has been alleviated by "window harvesting" instead of direct combining. As soon as the kernels are mature, but before they are sufficiently dry for combine harvesting, the crop is cut and put into windrows where little shattering occurs. When sufficiently dry, the windrows are threshed with a combine.

Oats are commonly planted with vetch for hay. They are planted at a rate of 20 to 60 pounds of oats and 40 pounds of vetch per acre. This depends on the percentage of the two species desired at the time of cutting for hay. This mixture produces more tonnage of better quality hay than oats alone and the hay is more easily cured than when vetch is grown alone. The oats support the viny vetch plants so that they are less likely to be weather damaged. For best quality, oats should be harvested when the kernels are in the dough stage and vetch when the first pods are turning brown.

Rye

A small grain of relatively minor importance in the United States, rye is, nevertheless, quite important the world over as a bread grain. It is also planted for pasture and green manure. Rye can be grown in every State of the Union and is the hardiest of all cereals. Rye usually yields less grain than winter wheat under conditions favorable for wheat because of its shorter growing period and heavier straw growth, but will be more productive than other grains on infertile, sandy, or acid soils. The grains of rye shatter easily and the plant volunteers quite freely. The plant usually thrives under adverse cultural conditions.

Rye is an annual or winter annual grass like wheat and barley. The stems of rye are longer and stronger than wheat. The roots branch profusely which might be one reason rye grows better on sandy soils. The inflorescence of rye is a spike with a single spikelet at each rachis joint. There are generally two fertile flowers in each spikelet. Rye is a naturally cross-pollinated plant, with the flower remaining open for some time. Approximately 50 percent cross-pollination can be affected. This is brought about by a high degree of self-sterility.

Cultural requirements of rye are similar to those of wheat. Winter rye should be planted as early as possible in order to utilize the pasture it provides. Spring rye, like all spring sown small grains, should be sown as early as is feasible. Seeding rate is generally four to six pecks per acre.

Rye is usually harvested and threshed like other small grains except where special use is made of the straw. When harvested by hand, it is usually harvested in an earlier stage because of the intense shattering.

Approximately one-third of the rye grain harvested is used for human food. When ground for flour, it is usually mixed with one-fourth to one-half wheat flour before it is baked. Another third of the grain production is used for the distillation of alcohol. The other one-third is used for livestock feed. It is usually mixed with some other feed grain to increase palatability.

One of the major diseases of rye is a fungus disease called ergot. The spores infect the rye flower during blossoming. Because of the cross-pollinating nature of rye, and the floret remaining open for pollen reception, rye is especially susceptible to ergot infection. When rye grain containing more than 0.5 percent ergot sclerotia is fed to livestock, it will often cause abortion in pregnant animals. The ergot sclerotia is gathered from the fields in the Mediterranean area for use in drug preparations.

Millets

The millets as a group are used for forage and grain. In much of the world, the millets are considered as grain crops only. The millets are all annuals of the grass family, but include several genera. The principal species are:

1.	Proso, or hog millet	-	Panicum miliaceum
2.	Foxtail millet	-	Setaria italica
3.	Pearl millet	-	Pennisetum glaucum
4.	Japanese millet	-	Echinochloa frumentacea
5.	Finger millet	-	Eleusine coracana

The millets are adapted to areas of spring sown small grains, but are planted later, requiring warm weather during their growing season. They usually require 60 - 90 days to mature, escaping periods of severe drought. While they have the lowest water requirement of any grain crop, they are less resistant to drought because of their shallow root system.

Seedbed preparation for the millets is similar to that for spring sown small grains. A firm seedbed is essential because of the small seed involved. Weeds should be controlled up to the time the crop is planted because the seedlings are small and compete poorly with weeds until they have attained some size. Close spacing helps millets suppress weeds.

Harvesting is difficult. The seeds do not ripen uniformly in the head, therefore, some seed has shattered before all is ripe. The plants are usually cut when part of the head is still green, allowing the seed to ripen "in the shock".

The grain of the millets is not used to any large extent in the United States. It is fed to livestock and poultry. In Asia and Africa, however, it constitutes a very important food crop. It is used as a cereal in soups, and is also ground into flour and made into bread. It also serves as a base for the manufacture of beer and other hard liquors.

UNIT V - PULSE CROPS

A. INTRODUCTION

Pulse crops make up a large part of the food crops grown throughout the world. They are defined as leguminous plants or their seeds used for food. The need for fats and proteins the world over has caused an increase in the use of various pulse crops.

Some of the major pulse crops grown throughout the world are: soybeans, field beans, peanuts, mung beans (grams), chickpeas, lentils, and cowpeas.

B. SOYBEANS

Soybeans have been a prime source of protein in China for many generations enabling millions of people to live in that country. It is one of the oldest of cultivated crops.

The soybean has about the same cultural requirements as corn. In general, combinations of high temperatures and low precipitation are unfavorable. Seed produced under these conditions tend to be low in oil content and quality. The plant is sensitive to over irrigation, but can withstand a relatively wet growing season. The period of germination is the most critical stage in plant growth. Excess moisture or prolonged drought can be particularly injurious at this time. The soybean plant is less susceptible to frost than the corn plant. They are very susceptible to photoperiod variations. A mean temperature of about 75 degrees appears to be the best for most varieties.

Soybeans grow on nearly all types of soil, but are especially productive on fertile loams. They are better adapted to low fertility soils than is corn, provided the proper strain of nitrogen-fixing bacteria is present. Bacteria can be introduced by seed inoculation.

Soybeans are summer annual plants, erect, bushy and rather leafy. They grow several feet high, have trifoliate leaves which tend to drop off when the seed pods mature. The seed pods are developed from the base of the main stem progressively upwards. Each pod contains one to four seeds. The soybean is normally self-fertilized with pollination occurring about as soon as the flower opens.

In general, the land for soybeans should be prepared in the same way as for corn. The seed should be inoculated with the correct strain of bacteria so nitrogen fixation can take place. The seed should be planted at the same time as corn and in rows for seed production.

Seeding rate will vary with seed size. The rate should provide enough seed to space the beans about one inch apart in the row. Seeding depth should not exceed two inches even on a light soil, as reduction in stand may occur.

Harvesting should take place when the seed reaches the hard dough stage. By this time, most of the leaves have turned yellow and dropped. Care should be taken in rubbing the beans from the pod so that not many of the seeds are broken and split.

Soybean seed is very high in protein, averaging about 40 percent. The oil content ranges from 14 to 24 percent or more. In general, soybeans with a low fat content are high in protein and vice versa. Soybean protein contains all the essential amino acids for animal and human food. Like other edible legume seeds, they are high in Vitamin B. It is low in starch and, as such, is very useful as a diabetic food. Soybean flour will make a good bread when mixed with wheat flour.

C. COWPEAS

This large seeded legume is now being greatly replaced by soybeans. Cowpeas are apparently a native to Central Africa where it has been cultivated for human food. It is a warm-weather crop grown primarily under humid conditions. It is similar to corn in its climatic adaptation except that it requires a higher amount of heat. It is sensitive to frost in the fall and the spring. Severe drought is very detrimental to seed formation. The primary soil requirements are good drainage and the presence of the proper nitrogen fixation bacteria.

The cowpea is an annual herbaceous legume, fairly leafy with trifoliate leaves. The growth habit is rather indeterminate, continuing to blossom and produce seed until checked by some adverse conditions. The cowpea is largely self-pollinated.

Cowpeas succeed on a seedbed prepared as for corn. For best results, cowpeas must be planted in warm soil after all danger of frost is past. Seeding rate is not quite as heavy as soybeans. Spacing in the row should average about two to three inches, with the seeding rate varying between 30 to 45 pounds of seed, depending on the size.

When about one-half to two-thirds of the seed pods have matured, the cowpeas should be harvested. Often the seed pods are harvested by hand and the seed flailed out of the pod. Care should again be exercised so the grains are not damaged.

Cowpea seed is high in feed value but is generally considered to be too valuable or too low yielding to grow for livestock feed. The seed of some varieties is a popular food, being used in the pod, shelled green, or shelled dried. The grain is high in protein and low in carbohydrates.

D. FIELD AND MUNG BEANS

The bean is a highly nutritious low-cost protein food, which became extremely important during past world wars. It is probably a native to South America, but has spread to every portion of the earth.

The bean plant is a warm-season annual adapted to a wide variety of soils. The best temperature for growth is between 65 and 75 degrees Fahrenheit. High temperatures interfere with seed setting and low temperatures are unfavorable for growth. Dry beans are generally produced where the rainfall is light during the latter part of the season. Beans require a minimum frost-free season of about 120 to 130 days to mature a seed crop. Harvest season should be relatively free from rain to avoid discoloration of seed. All varieties are more or less flat-seeded.

Beans are all summer annuals and have a growth habit that is either bushy or trailing (vine-like). The field beans have a fibrous pod which should be borne above the ground. It should also ripen uniformly, and not shatter at maturity. They are normally self-pollinated. Seed color varies from white to black.

Commonly called gram (green or golden), mung beans are grown chiefly for human food in the southern half of Asia and in Africa. It is the source of the common bean sprout used in chop suey. The black gram or urd, grown chiefly in India for human food, is somewhat similar to the mung bean.

E. CHICKPEAS

The chickpea is commonly called the garbanzo bean. It is grown only to a very limited extent in the United States, being very important in the Mediterranean area and South Asia. It is a plant that is a native of Europe, and best adapted to warm semiarid conditions. The plant is a low bushy annual with hairy stems. It is grown and handled similar to field beans and the threshed seed is prepared for food in much the same manner as are dried beans. Roasted beans have often been substituted for coffee.

F. LENTILS

This legume has been grown in the Mediterranean regions since ancient times. Considerable quantities are used in soups. The lentil plant is a weakly upright annual with compound leaves. The seeds are thin and lens-shaped, usually smaller than pea seed, and of various colors.

G. PEANUTS

The peanut, commonly called groundnut, goober pea, pindar, etc., is a pea rather than a nut. It is the third most important cash crop grown in the southern United States. It is another crop that has its importance because of the oil and protein content of the seed. The popularity of peanuts is enhanced by the fact that they require less fertilizer than do most other crops.

The peanut is believed to be native to the tropics of South America, but was introduced to the United States from Africa. The most favorable climatic conditions for peanuts are moderate rainfall during the growing season, an abundance of sunshine, and relatively high temperatures. The best crops are obtained where the annual rainfall is between 40 and 50 inches. Peanuts require an average frost-free period of 200 days or more and a growing period of up to 150 days.

The best yields of peanuts can be achieved from a light sandy loam soil that is well drained. Light sandy soils offer less resistance to the penetration of the pegs that must enter the ground in order for the pods to develop.

The cultivated peanut is a legume classified botanically as Arachis hypogaea. It has a well developed tap root with numerous lateral roots that extend several inches into the ground. The plant is a low annual with a central upright stem. Peanut varieties are readily separable into bunch and runner types.

The flowers are borne in the leaf axils, above or below the ground. The corolla is borne at the end of the calyx. After pollination takes place, the section right behind the ovary elongates and pushes the ovary into the soil where the pod is developed. Flowers of peanuts are perfect and generally self-pollinated. Usually from one to three seeds are formed in each pod.

Freshly harvested seed should not be planted. Usually, the dormancy of fresh seed can be broken by dry storage for several weeks or months depending upon the variety. Under proper storage conditions, peanut seeds retain their viability for three to six years.

Either shelled or unshelled peanut seed can be planted. Shelled seed will germinate quicker but will not have quite as high emergence because of damaged seed. All seed should be treated with a good fungicide before planting.

Seedbed preparation should be rather thorough. This aids the later penetration of the pegs. Seed is planted after the danger of the last spring frost is past. They are generally planted about the same time as cotton. About 20 pounds of hand shelled seed or 40 pounds of seed in the hull is required to plant an acre. The seed is planted in rows 30 to 36 inches wide with the plants about three inches apart in the row. Cultivation of peanuts is similar to that of soybeans.

Harvesting of peanuts is quite exacting. Peanuts are ready for harvest when the kernels are full grown, with the skins displaying a distinct texture and the natural color of the variety. Peanuts are generally harvested before the vines are killed by frost. Most peanuts are loosened from the soil with special diggers, usually of the plow type. The vines are then lifted, shaken to remove the soil, and left in small piles until thoroughly wilted before being stacked. The crop is allowed to cure in the stack for three to six weeks or longer before threshing. When sufficiently dry, the pods are stripped from the vine and bagged. The threshed vines are often baled for hay.

Peanut seed should be dried down to a moisture content of five percent or less or the nuts will begin to turn rancid. An average ton of cleaned unshelled peanuts yields about 530 pounds of oil, 820 pounds of meal, and 650 pounds of shells. The nuts contain 40 to 48 percent oil and 25 to 30 percent protein. They are very high in the amino acids that are essential for animal growth. Like all other large seeded legumes, peanuts are also an excellent source of the vitamins thiamin, riboflavin and niacin.

UNIT VI - SUGAR AND FIBER CROPS

A. INTRODUCTION

Each year, the average American consumes over 50 pounds of sugar. About half of this is produced within the 50 States and Puerto Rico; the other half is imported from other countries. Whether produced from beets or from cane, the sugar furnishes a tremendous amount of the energy required by a person. In actual fact, there is no difference between the sugar derived from sugarcane or sugar beets.

B. SUGARCANE

Sugarcane is a tropical plant that requires from 8 to 24 months to mature. A period of high temperatures that permits rapid growth for eight months or more is usually followed by a period of low growth activity and increased sugar storage. Sugarcane is generally considered ripe when sugar content has reached its maximum.

Sugarcane soils should be well drained and well supplied with minerals and organic matter.

The plant is a tall perennial grass averaging fifteen feet in height or more. The culms are usually bunched into stools of 5 to 50 each. The internodes are comparatively short, usually two to three inches in length, with a root band and a single bud or eye at each node. The leaf blade is usually erect, with the sheath folded around the stem.

Seed is seldom produced on sugarcane in the United States. It is usually harvested before the inflorescence appears. This, of course, calls for vegetative reproduction.

Seedbed preparation for sugarcane is very similar to that for corn in the same region. Ridging or throwing the land into beds is practiced in some areas. A water furrow is left between beds where irrigation is practiced.

Sugarcane is produced commercially from stalk cuttings. The cane is stripped and cut into two or three foot lengths. These cuttings are planted in furrows in one to three continuous lines. Spacings between rows vary from four to seven feet. The seed stalks are covered two to eight inches deep, or only deep enough to avoid frost injury. The canes can be planted in the fall or spring, depending on the available supply of labor. When fall planted, the crop makes little growth before spring.

In those areas where sugar is produced, more than one crop of sugarcane may be harvested from a single planting. The first crop is known as the plant cane, while subsequent crops are known as stubble or ratoon crops. Two ratoon crops are quite common.

After growth is well started in the spring, fertilizer is applied in the furrows next to the row and the furrows are levelled. Cultivation to control weeds is necessary until the plants shade the ground.

Sugarcane begins to mature with the advent of cool nights in the fall. It continues to mature until its growth is checked by frost or other adverse conditions. Hand harvesting proceeds after the right stage is reached. Occasionally the fields are burned to remove excess leaves and trash from the standing stalk. Other producers strip the leaves from the stem as the stalks are cut. Specially designed knives and stripping implements are used. About 20 to 30 percent of the total crop is leaves and tops. Mechanical harvesters are beginning to be used which cut, top, and load the cane. Usually loads of two to three tons are hauled to the mill.

After harvesting, the cane field is generally burned, if it was not already, to clean off the excess leaves and debris. If the crop is to be ratooned, the field is thoroughly irrigated to encourage early growth.

Upon arriving at the mill, the stalks are cut, sometimes shredded, and then passed between a series of heavy grooved iron rollers to press out the juice. The crushed residue is known as bagasse. Hydrated lime in water is added to the strained juice after which the limed juice is heated with steam. The impurities unite with the lime and appear on the surface as scum or at the bottom of the clear juice as sediment. The clear juice, along with the settlings, is conducted into a series of vacuum evaporators where it is concentrated to a semi-sirup containing about 50 percent sucrose. This sirup is then pumped into vacuum pans where it is further evaporated and finally crystallized. The mixture is then separated by centrifuge with the resulting raw sugar being cleaned and refined.

By-products of sugar extraction are blackstrap molasses, bagasse or stalk residue, and filter press cake. Blackstrap molasses is used for either livestock feed or for alcohol production. When a surplus occurs, it is generally poured back onto the cane field as a fertilizer. The cane fibers in bagasse are used for the manufacture of wallboard, commonly known as Celotex or soft board. Most of the bagasse, however, is burned for fuel in the operation of the sugar mills. Filter press cake has a fertilizer value equal to barnyard manure.

C. SUGAR BEETS

Sugar beets have been one of the most uniformly profitable cash crops in many irrigated valleys in the western United States. A sideline of sheep and beef cattle fattening has grown along with the sugar beet industry. This has been brought about by the amount of by-products available from the sugar mills as well as the hay and other feed crops grown in rotation with the sugar beets.

About 35 percent of the world's supply of sugar is produced from the beet. Beet sugar cannot be distinguished from cane sugar.

Sugar beets can only be grown on fertile soils. The soils require a high percentage of organic matter supplied either naturally or through heavy applications of barnyard manure. Green manure crops are often plowed down prior to planting beets. The sugar content of beets is generally the highest on those soils that produce the highest tonnage.

Irrigation water is necessary for successful commercial production where the rainfall is less than 24 inches. Sugar beets germinate well when the soil temperature is about 60° F. The plant is uninjured by cool nights. Cool autumn weather favors sugar storage in the roots. Temperatures above 86° F. retard sugar accumulation.

The newly emerged seedling may be killed by a temperature of 25° F. Later, the plants become more resistant to the cold. The mature plant is able to withstand fall frosts, but a temperature as low as 26° F. usually causes foliage injury. Should new leaf growth occur, sugar content declines.

The sugar beet is a biennial and as such will normally complete its vegetative cycle in two years. It develops a large succulent root the first year in which much food reserve in the form of sugar is stored. It is in this stage that the plant is harvested for sugar. During the second year it produces flowers and seeds. Prolonged cool periods, accompanied by the effects of long photoperiods, often brings about the initiation of seedstalks and flowers during the first year. This behavior, known as bolting, produces a root that is almost devoid of sugar content. The beet is a cross-fertilized plant, showing a striking lack of uniformity in foliage characters.

The seed produced by the beet is an aggregate, hard, irregular shaped body, which usually contains two to five seeds. A suitable single germ seed ball is slowly being perfected. This alleviates the hand labor involved in getting single plants properly spaced in the row.

Sugar beets are almost all grown in rotation with legumes and small grains. Sugar beets are usually the second crop to follow the legume. Because of the weed control in either corn or cereal production, beets will be a cleaner crop. Legumes themselves often foster certain diseases that are detrimental to sugar beets. Large applications of barnyard manure are often applied and plowed down on beet land. Phosphorous is the major element of commercial fertilizer that is applied to sugar beets.

Sugar beet roots sometimes extend five to six feet into the soil. Therefore, deep plowing (eight to twelve inches) is often recommended. A mellow seedbed should be provided for the small seedlings.

Planting rates vary according to the type of seed used, averaging about fifteen pounds of unsheared seed per acre. The rows are usually thinned out to leave one plant every ten to twelve inches. Thinning should be done when the plants have eight to ten leaves. A considerable amount of cultivation must take place during the growing season to keep the beets weed free.

Irrigation water is applied about every two weeks in most areas. Beet leaves will show a slight wilting when water is needed. It is better to apply water before this wilting occurs as yields will be slightly reduced. At least 50 percent of the total water holding capacity in the top twelve inches of the soil should be maintained. The crop usually requires two to six inches of water at each application or 12 to 36 inches for the season. The final irrigation should provide sufficient moisture for the beets to complete their growth and, in addition, should leave the soil moist enough so the roots may be easily lifted.

Sugar beets should be left in the field until they reach a maximum sugar content. Usually the sugar company makes a root analysis and indicates when harvest should start. The beets are then loosened and pulled from the soil, the soil is crumbled from the root and the tops are cut off. The beets are then piled until the factory begins processing.

In sugar manufacture, the process is quite similar to that of cane. About 300 pounds of sugar is received from a ton of beets, or about 3,600 pounds of sugar per acre. By-products are beet pulp which is used for livestock feed -- either fresh or dried; and molasses which is often added to the pulp, fed to livestock, or used in the manufacture of alcohol.

Beet tops are utilized also. They are fed to sheep and cattle, either fresh or ensiled. The cattle are often turned into the field to pick up the tops and eat them there. However, it is more efficient to harvest the tops and haul them to the livestock.

Seeds of sugar beets are produced in mild climates where they are not killed by winter temperatures. The seed of the beet is planted in the fall of the year, left unthinned, and given enough water to keep them alive over winter. Seed is produced the following year on the overwintered plant. The seed stalks are cut and cured and finally threshed with common threshing equipment. In the northern areas, the seed must be imported each year for beet production.

D. COTTON

Cotton makes up more than half of the fiber used by man. It is a very important fiber crop grown in many countries. In addition, cottonseed plays a very important role for livestock feed as a protein supplement.

Cotton has been grown in India for more than 2,000 years. Columbus found cotton growing in the West Indies. It was grown in the Virginia Colony in 1607, but large scale production was not started until after the invention of the cotton gin in 1794.

Climatic conditions favorable to cotton production are a mean temperature during the summer months of not less than 77° F, a favorable distribution of rainfall, sunshine and temperature, a frostless season of 180 to 200 days and a minimum rainfall of 20 inches a year with suitable seasonal distribution. A rainfall pattern of 60 inches would not be too much if distribution was favorable. The growing conditions most optimum for cotton are a mild spring with light frequent showers; a warm, moderately moist summer; and a dry, cool, prolonged autumn. Rainy weather, when the bolls begin to open, retards maturity, interrupts picking and damages exposed fibers. In general, cotton is very indeterminate in growth habit, as well as very insensitive to length of day. It will produce flowers throughout the year under warm conditions.

Cotton grows well on moderately fertile soils. The best cotton lands are mixtures of clay and sandy loam, containing a fair amount of organic matter and a moderate amount of available nitrogen, phosphorous and potash.

Classification

Cotton belongs to the Malvaceae or mallow family. The genus Gossypium to which cotton belongs contains several species. Upland cotton produces fibers ranging from three-fourths to one and one-fourth inches or more in length which are of medium coarseness. The lint fibers adhere strongly to the seed and the bolls usually contain four or five locks.

Sea Island and American Egyptian cottons have extra long, fine fibers, one and one-half to two inches or longer. The lint is readily detached from the seed. The bolls usually have only three locks.

The Asiatic cottons produce fibers that are coarse and short (between one-half to seven-eighths inches long).

Cotton Plant

The cotton plant usually is considered an annual, although it is a long lived perennial in the tropics where the mean temperature does not fall below 65° F. The plant is herbaceous, or tree like, and attains a height of two to five or more feet. It has a main stem from which many branches arise. The main stems are erect and branching, the branches developing from buds at the nodes of the main stem. The leaves arise on the main stem in a regular spiral arrangement. At the base of each cotton leaf petiole are two buds, the true axillary bud which continues to make a vegetative growth. and an extra axillary bud which produces the fruiting branch. Only fruiting branches bear flowers. Normally flowers are not formed on the lower third of the plant.

The leaves of cotton are borne on petioles and are three, five or seven lobed. The leaves and stems are usually covered with fine hairs.

The flowers appear on alternate sides of the fruiting branch. The total flower consists of three relatively large leaflike bracts at the base of the flower, above which is a true calyx consisting of five unequally lobed sepals. The corolla consists of five petals which range in color from white to yellow to purple depending on the type of cotton. The staminal column bears ten more or less double rows of stamens while the pistil is made up of from three to five carpels. This may be determined from the number of lobes on the summit of the stigma, the carpels later developing into locks in the boll.

The cotton boll is one and one-half to two inches long among the common varieties, and it requires 60 to 80 bolls to produce a pound of seed cotton. The boll splits open at maturity shedding the lint. The number of bolls varies with the variety, the type of soil, the cultural method, and the climatic conditions. The number of seeds in one lock is usually about nine so that the seed produced from one boll varies between 27 to 45.

Flowering in cotton plants begins from eight to eleven weeks after planting and continues until growth is stopped by frost, drought or other causes. Many more bolls are produced than the plant is able to mature. As many as 50 percent of the immature bolls are dropped under normal conditions within eight to ten days after flowering. The length of time between flowering and the opening of the boll is about six to eight weeks. Cotton is often cross-pollinated but natural crossing rarely exceeds 20 percent.

Cotton fibers are slender single-cell hairs growing out from certain epidermal cells of the cottonseed. The fibre reaches full size within a period of three weeks after fertilization of the flower. For the next three weeks the fibers grow thicker. Fluctuations in available moisture during this period causes the cotton fiber to be weak and thin walled. Other things being equal, long fibers give a smoother and stronger yarn than do short fibers. Short fibered varieties, however, yield a higher percentage of fiber than do longer fibered types.

Cultural Practices

A relatively compact seedbed is usually required for cotton. The fuzz on cotton seed prevents close contact with the soil unless the soil is pressed around the seed. A seedbed free from trash helps to eliminate this problem. Cotton may be planted on ridges, on the level or in furrows, depending on the amount of soil moisture available. It is a common practice in many developing countries to plant cotton on freshly cleared land or land that is put back into cultivation after "resting" several years under elephant grass. The massive amounts of trash and undecomposed vegetation in these conditions call for an excessive seeding rate to establish a good stand.

Cotton is planted when the soil is warm -- when the temperatures are 60^{o} F. or higher. The seed is usually planted no deeper than one to one and one-half inches, at a rate of 30 to 40 pounds of seed per acre. A population of 7,000 to 14,000 plants per acre is considered a good stand, depending on the moisture and fertility available.

Insect Control

No other crop seems to require, nor to receive, such a thorough insect control program. The boll weevil is probably the most destructive of the cotton insects. The female punctures the squares or bolls in which it deposits its eggs. The larvae, of course, destroys the lint. The boll worm, seemingly prevalent all over the world, also destroys the contents of the boll. Aphids, leafworms, webworms, etc., are all of economic importance because of their habits of feeding on the juices of the plants. Cotton stainers puncture the bolls and seeds, causing complete destruction or at least staining the lint.

Such cultural practices as crop rotation and the uprooting and burning of old cotton stalks and gin trash keep some insects in check. Most countries also have a recommended spraying schedule which combats the major insect pests during the growing season. For the most part, DDT or BHC will take care of the worst infestation if used in the right amounts at the correct times.

Harvest

In most of the world, cotton is picked by hand. After the bolls are open, the lint is merely stripped from the locks. Often, two or three pickings are required as later bolls open. Hand picking will allow for better grades of cotton to be sold if a little bit of selection is practiced as the picking is done. Occasionally two sacks are carried so that the cotton can be graded as it is picked in the field.

At one time, snapping of cotton was practiced. This consists of the entire boll being pulled from the stem. The burs and seeds are then separated at the gin with a special extractor. Although snapping is faster and cheaper than picking, the amount of trash gathered with the cotton is increased, lowering the grade.

Mechanical harvest of cotton is becoming quite prevalent today. The machines have been developed to such a high degree that 95 to 98 percent of the lint is taken from the plants; however, a higher amount of trash is also accumulated. The cotton plant has been changed by breeding to adapt to machine harvest. The bolls must all open within a reasonably short period of time, and the plant must be fairly uniform in size and height. The field is sprayed with some defoliant shortly before harvest so the plant will lose its leaves. The defoliation of the plant cuts down on the amount of trash in the harvested lint as well as permitting earlier harvest due to quicker drying of the plant.

Cotton lint is generally sold on the basis of three factors -- length, strength, and cleanliness. Once ginned and graded, the cotton lint is baled and weighs about 500 pounds each. Clean seed cotton is about 32 to 45 percent lint, thus, 750 to 1,000 pounds of seed are obtained for each 500 bales of lint produced. Cottonseed meal and cake, which are secured in the production of oil from cottonseed, are among our most important feeds containing 41 percent protein or more. Cottonseed hulls are one of the most common roughages in the South, being left over after the seed has been crushed for oil extractions.

UNIT VII - OIL CROPS

A. INTRODUCTION

Numerous crops are grown throughout the world for their oil bearing seeds. This oil is used as a condiment or a cooking oil, but is sometimes grown for commercial purposes. For the most part, the oilseeds are pressed and the oil refined for home use. The meal which is left over after oil extraction is generally used for cattle feed or is returned to the field as fertilizer. Although there are many crops which fit into the oilseed category, the chief ones the world over seem to be flaxseed, castor, sunflower, safflower, niger, mustard, and sesame. Cotton, soybean, and corn are also oil producers and have been discussed in previous sections.

B. FLAXSEED

This is an annual plant which can be grown for both seed and fiber. It requires moderate to cool temperatures and between 18 to 30 inches of rainfall. It has a very shallow root system so is very susceptible to moisure fluctuations. It will grow from 12 to 48 inches high from a short taproot. The plant has many branches and bears a flower of five petals and a five-celled boll or capsule containing a maximum of ten seeds. It is normally self-pollinated.

Flax is a very poor weed competitor and is best grown following either a clean-cultivated row crop or a legume. It can serve as a companion crop to an undersown legume such as alfalfa or clover.

Flax requires a firm weed free seedbed. Commercial fertilizers are seldom applied to flax lands. Flax is generally sown as early as possible in the spring after small grains have been seeded. It is generally broadcast or sown with a grain drill at a depth of one inch or less.

Flaxseed is harvested in the same manner as the small grains. The capsules must be very dry in order to flail the seed from the plant. The seed should contain less than eleven percent moisture for proper and safe storage. Fairly close to one-third of the flaxseed is recovered in oil from plump well-matured flaxseed. About 80 percent of the linseed oil is used in paints and varnishes. The cake that is left over is used as a feed for livestock.

C. CASTOR

The castor plant is another oil crop that is grown because of the commercial value of the oil. It is grown on a very limited area in the United States as a cultivated crop, but is harvested from volunteer or wild plants in Africa and Asia.

The castorbean plant is adapted to areas having a frost-free period of 180 days or more and an average rainfall of about 20 inches. The crop can be successfully grown under irrigation. The castorbean requires a well-drained soil, preferably loam, of good physical condition.

The castorbean belongs to the Euphorbia family and is a short-lived perennial. In the tropics it will grow into a tree 20 to 30 feet high, but in the U.S. it is treated as an annual. It has very large leaves and produces monoecious flowers. The pistillate flowers are produced in the upper part of the raceme while the staminate flowers are produced below. Cross-pollination as a consequence is quite high. The seed is borne in a three-celled capsule, one seed per cell. The seed is mottled and quite similar in appearance to the bean. Not being a legume, the fruit is not a bean.

Castorbeans require the same type of seedbed as is used for corn. It can be planted much the same as corn but generally requires more cultivation for weed control. Optimum populations are about 5,000 to 8,000 plants per acre. The seed should be planted two to three days earlier than corn.

Castorbeans must be harvested before the ripe seeds have had a chance to shatter. The most satisfactory method of harvest is to strip all ripe pods from the raceme. They should be stored and dried and then hulled from the usual spiney pods. Special hulling machines for castorbeans have been recently developed which help alleviate this problem.

Castorbeans contain 35 to 55 percent oil averaging about 50 percent. The oil is extracted usually by pressure only, without grinding or heating. The oil is used chiefly in the manufacture of soap, linoleum, etc. It is also used as a lubricant for marine engines and airplanes. Recent advances in processing have given it drying properties so it can now be used in paints and varnishes.

The castorbean and presscake are poisonous to humans, livestock, and poultry. The leaves of the plant are also poisonous to livestock.

D. SESAME

Commonly called sim-sim in various sections of the world, sesame is grown because of the edible oil that can be pressed from the seed. It is an erect annual herb reaching a height of three to five feet. It is generally planted in cultivated rows about three feet apart in the spring after the danger of frost. A stand of plants about two to four inches apart in the row is desired. When mature, the seed shatters excessively and should be handled with extreme care.

The chief use of sesame is for its edible oil. It makes a good salad oil and is also used for lighting purposes in Asia. The seed is often sprinkled on certain types of bread, rolls, and cakes just before baking.

E. SAFFLOWER

This is one of the several plants belonging to the Composite family that is grown for its oilseed. It is adapted to much the same area as flax, but usually does not yield quite as high in pounds of oil per acre. Safflower does not yield flax in pounds of seed per acre, but the seed is about 40 to 55 percent hull. The safflower meats yield a higher percentage of oil.

Safflower is an annual erect herb one to three feet high and branched at the top. The leaves are quite spiny and the Composite flowers produce small white seeds quite similar in shape to a sunflower.

Safflower is not a good weed competitor and should be planted on clean ground and in cultivated rows. Seedbed preparation, drilling, and irrigation requirements are much the same as for small grains. In the highlands of Africa, safflower is planted at a small rate with the small grains.

When the seeds are hard and dry they are ready to harvest. The crop does not lodge and seeds seldom shatter. The crop is well adapted to combine harvest. Because of the spiny leaves, the plants are not easily harvested by hand.

When the seed is crushed to extract the oil, the oil meal will naturally contain a high percentage of fibre but compares quite favorably to cottonseed meal in livestock food value.

F. SUNFLOWER

Sunflower is a native plant of the United States. However, it is grown in other sections of the world chiefly for the edible seed. It is adapted for seed production where corn is successful in the nothern two-thirds of the United States.

It is a member of the Composite family. It is a stout erect annual, five to twenty feet in height with rough hairy stems one to three inches in diameter. The head produced at the top of the stalk is mostly cross-pollinated.

Sunflowers can be planted in seedbeds prepared like that of corn. They are usually planted in 36 inch rows spaced 12 inches apart in the row. Sunflower seeds are ready for harvest when the moisture content is down to eight or nine percent.

About 35 to 50 percent of the seed is hull. The whole seed contains 24 to 35 percent oil or 40 to 45 percent of the hulled seed. Sunflower oil cake contains about 35 percent protein. The oil of sunflowers is used mostly in shortening, cooking oils and margarines.

TABLE 5

APPROXIMATE NUMBER OF PLANTS PER ACRE
AT VARYING WIDTHS AND SPACINGS IN THE ROW

Row Width (inches)	Seed spacings in the row - (inches) 3	6	8	10	12	15	18	24
6	348,500	174,240	130,700	104,500	87,100	69,700	58,100	43,600
12	174,200	87,100	72,600	58,100	43,600	34,800	29,000	21,800
15	139,400	69,700	58,100	46,500	34,800	29,000	23,200	17,400
18	116,200	58,100	46,500	34,800	23,200	23,200	19,400	14,500
21	101,600	49,800	37,300	29,900	24,800	20,300	17,000	12,700
24	87,100	43,600	32,700	26,100	21,800	17,400	14,500	10,900
28	77,400	37,300	28,000	22,400	18,700	15,500	12,900	9,700
32	67,800	32,700	24,500	19,600	16,300	13,500	11,300	8,500
36	58,100	29,000	21,800	17,400	14,500	11,600	9,700	7,300
38	55,200	27,500	20,600	16,500	13,800	11,500	9,200	6,900
40	52,300	26,100	19,600	15,700	13,100	10,900	8,700	6,500
42	49,800	24,900	18,700	14,900	12,400	10,400	8,300	6,200

TABLE 6

CROP PLANTING TABLE

Crop	Lb./Acre	Wt./Bu.	Planting Depth In.	Type of Planting	Recommended Seeds/Foot of Row
Corn	10 - 14	56	2 - 3	r. d.	
Soybeans	40 - 60	60	2	r. d.	10 - 12
Sorghum	2 - 6	56	1 - 2	r. d.	3 - 6
Wheat	60 - 90	60	1 - 2	d.	
Barley	60 - 90	48	1 - 2	d.	
Rye	56 - 84	56	1 - 2	d.	
Oats	50 - 80	32	1 - 2	d.	
Flax	42 - 56	56	1 - $1\frac{1}{2}$	d.	
Beans	30 - 80	60	2	r.	3
Rice	125 - 200	45	1 - 2	d.	
Cotton	12 - 30	32	$1\frac{1}{2}$ - 2	r.	
Field Peas	120 - 180		$\frac{1}{2}$	d.	

TABLE 7

PLANT NUTRIENTS FOR DEFICIENCY SYMPTOMS

Functions of Plant Nutrients	Deficiency Symptoms in Crops
Primary Plant Food Element	
Nitrogen (N) Gives dark green color to plants. Promotes rapid growth. Increases yields of leaf. Improves quality of leaf crops. Increases protein content of food and feed crops. Feeds soil micro-organisms during their decomposition of low-nitrogen organic materials. If supply out of balance, with that of other nutrients, may delay flowering and fruiting.	Nitrogen (N) A sickly yellowish green color. A distinctly slow and dwarfed growth. Drying up or "firing" of leaves which starts at the bottom of the plant, proceeding upward. In plants like corn, grains, and grasses, the firing starts at the tip of the bottom leaves and proceeds down the center or along the midrib.
Phosphorus (P) - In fertilizer, stated in terms of available Phosphate (P_2O_5) Stimulates early root formation and growth. Gives rapid and vigorous start to plants. Hastens maturity. Stimulates blooming and aids in seed formation. Gives winter-hardiness to fall-seeded grains and hay crops.	Phosphate (P_2O_5) Purplish leaves, stems and branches. Slow growth and maturity. Small slender stalk in case of corn. In small grains, lack of stooling. Low yields of grain, fruit and seed.
Potassium (K) - In fertilizer, stated in terms of Potash (K_2O) Imparts increased vigor and disease resistance to plants. Aids in protein production in plants. Stiffens straw and stalk parts thus reducing lodging. Increases plumpness of grain and seed. Essential to the formation and translocation of starches, sugars, and oils.	Potash (K_2O) Mottling, spotting, streaking or curling of leaves, starting on the lower levels. Lower leaves scorched or burned on margins and tips. These dead areas may fall out, leaving ragged edges. In corn, grains and grasses, firing starts at the tip of the leaf and proceeds down from the edge, usually leaving the midrib green.

Functions of Plant Nutrients	Deficiency Symptoms in Crops
Potassium (K) (continued) Improves quality of fruits. Helps development of tubers. Aids in formation of anthocyanin (red color of leaves and fruit).	**Potash (K_2O) (continued)** Premature loss of leaves and small, knotty, poorly opened bolls on plants like cotton. Plants, like corn, falling down prior to maturity due to poor root development.
<u>Secondary Plant Food Element</u>	
Calcium (Ca) Promotes early root hair formation and growth. Improves general plant vigor and stiffness of straw. Facilitates improvement in soil structures. Neutralizes poisons produced in the plant. Encourages grain and seed production. Increases calcium content of food and feed crops. In certain forms, corrects soil acidity.	**Calcium (Ca)** Young leaves in terminal bud become "hooked" in appearance and die back at the tips and along the margins. Leaves have wrinkled appearance. In some cases, young leaves remain folded.
Magnesium (Mg) Is an essential part of chlorophyll. Necessary for the formation of sugar. Helps regulate uptake of other plant foods. Acts as carrier of phosphorus in the plant. Promotes formation of oils and fats. In certain forms, corrects soil acidity.	**Magnesium (Mg)** A general loss of green color which starts in the bottom leaves and later moves up the stalk. The veins of the leaf remain green. Cotton leaves often turn a purplish-red color between the veins. Weak stalks with long branched roots. Definite and sharply defined series of yellowish-green, light yellow, or even white streaks throughout entire leaf as with corn. Leaves curve upward along the margins.

Functions of Plant Nutrients	Deficiency Symptoms in Crops
Sulfur (S) Is an essential ingredient of protein. Helps maintain dark green color. Promotes nodule formation on legumes. Stimulates seed production. Encourages more vigorous plant growth. In certain forms, corrects soil alkalinity.	**Sulfur (S)** Young leaves light green in color, have even lighter veins. Short, slender stalks, yellow in color. Slow, stunted growth.
Boron (B) Growth of terminal buds. Increases yield or improves quality of alfalfa, fruit or vegetables. Associated with calcium utilization and sugar transfer, within the plant. Important for seed production of legumes. Deficiency may cause barren stalks on corn. Needed particularly on muck soils.	**Boron (B)** Boron need is indicated by cracked stem of celery, brown rot of cauliflower, heart rot of turnips, yellow top of alfalfa, corky core of apples and black heart of table beets, dry rot of sugar beets. Sometimes results in lack of seed in corn and bolls on cotton.
Copper (Cu) Activation of enzymes. Light reactions in plants. Important in reclaiming and utilizing peat and muck soils. Flower and bud formation.	**Copper (Cu)** Copper deficiency causes dieback in citrus and on muck soils, blasting of onions and truck crops.
Iron (Fe) Enzyme activity. Synthesis of protein. Associated with production of green chlorophyll. Often unavailable in forms present in overlimed, alkaline, or highly calcareous soils.	**Iron (Fe)** Iron need is shown by pale-yellowish color foliage, in the presence of adequate amounts of nitrogen and on soils that are high in lime or manganese. Light green band along margin of leaves. Short and much-branched roots.

Functions of Plant Nutrients	Deficiency Symptoms in Crops
Manganese (Mn) Enzyme activity. Accelerates germination and maturation. Increases availability of calcium, magnesium and phosphorus. Promotes soil oxidation. Aids in the synthesis of chlorophyll and functions in photosynthesis. Deficiency often associated with soil alkalinity or overlimed soils.	**Manganese (Mn)** Manganese deficiency is shown by pale green to yellow and red colors between green veins of leaves of tomatoes and beets, Resinous spots on leaves of citrus, chlorosis of crops such as spinach and soybeans on overlimed soil, and "grey speck" on oats.
Molybdenum (Mo) Is essential in nitrogen fixation and utilization by legumes. May be important in acid soil regions on such crops as legumes, tomatoes, beets, crucifers. Corrects Whiptail of cauliflower and Yellow Spot of citrus.	**Molybdenum (Mo)** Stunted and yellow in color, closely resembling nitrogen deficient plants.
Zinc (Zn) Enzyme activity. Necessary for normal chlorophyll production and growth. Often deficient in available forms in alkaline or highly limed soils.	**Zinc (Zn)** Zinc deficiency is indicated by white bud of corn, rosette of pecans, little leaf of fruit trees, and frenching of citrus.
Chlorine (Cl) Growth and development. Maturity. Respiration. Most recent addition to the list of known essential plant nutrients. It is very seldom deficient under field conditions.	**Chlorine (Cl)** Generally there is no deficiency of chlorine in soils.

TABLE 8

WEIGHT OF SUBSTANCES

Product	Approximate Net Weight In Pounds per Cubic Foot
Apples	40
Barley	40
Brick Work	125
Coal	50
Cobblestone	150
Corn (ear)	28
Corn (shelled)	47
Cotton (bales)	30
Cotton (seed meal)	40
Cucumber	36
Egg Plant	26
Flint Rock	165
Hay (loose)	4
Hay (bales)	12
Hay (chopped)	10
Ice	58
Limestone (solid)	165
Limestone (ground)	82
Molasses	90
Oil Lubricating	57
Potatoes	48
Potatoes (sweet)	46
Rice (rough)	36
Rice	45
Sand	110
Tobacco (in bales)	35
Wheat	48

TABLE 9

USEFUL WEIGHTS FOR CROP PRODUCTION

Avoirdupois

1 ounce (oz.)	437.5 grains
1 pound (lb.)	16 oz.
1 lb.	7,000 grains
1 lb.	453.5924 grams
1 short ton	2,000 lbs.
1 short ton	907.2 kilograms
1 long ton	2,240 lbs.
1 long ton	1,016 kilograms
1 long ton	1.01605 metric tons
1 metric ton	2,204.7 lbs.
1 metric ton	0.98421 long tons
1 metric ton	1,000 kilograms
1 metric ton	26.792 maunds
1 kilogram	2.20462 pounds
1 pound	0.45359 kilogram
1 maund	82.257 pounds
1 maund	37.32421 kilograms
100 kilograms	1 quintal

Troy

1 penny weight	24 grains
1 oz.	20 penny weight
1 oz.	480 grains
1 lb.	12 oz.
1 lb.	5,760 grains

Apothecaries

1 scruple	20 grains
1 dram	3 scruples
1 oz.	8 drams
1 lb.	12 oz.

1 grain is the same weight in all three systems of measurement

GLOSSARY OF AGRONOMIC TERMS

A HORIZON	The surface and subsurface soil which contains most of the soil organic matter and is subject to leaching.
ACID SOIL	A soil with a pH reaction of less than 7.0 (usually less than pH 6.6). It has a preponderance of hydrogen ions over hydroxyl ions. Litmus paper turns red in contact with moist acid soil.
AERIAL ROOTS	Roots arising from the stem above the ground.
AGGREGATE	A mass or cluster of soil particles or other small objects.
AGRONOMY	The science of crop production and soil management. The name is derived from the Greek words agros (field) and nomos (to manage).
ALKALI SOIL	A soil, usually above pH 8.5, containing alkali salts in quantities that usually are deleterious to crop production.
ANNUAL	A plant that completes its life cycle from seed in one year.
ANTHER	The part of the stamen that contains the pollen.
ANTHESIS	The period during which the flower is open and in grasses when the anthers are extended from the glumes.
ASEXUAL	Reproduction without involving the germ or sexual cells.
AURICLES	Ear-shaped appendages as at the base of barley and wheat leaves.
AWN	The beard of bristle extending from the tip or back of the lemma of a grass flower.

B HORIZON	The subsoil layer in which certain leached substances (i.e., iron) are deposited.
BACKCROSS	Cross of a hybrid with one of the parental types.
BEARD	Awn of grasses.
BED	(1) A narrow flat-topped ridge on which crops are grown with a furrow on each side for drainage of excess water. (2) An area in which seedlings or sprouts are grown before transplanting.
BIENNIAL	Of two years' duration. A plant germinating one season and producing seed the next.
BLADE	The part of the leaf above the sheath.
BOOT	(1) The upper leaf sheath of a grass. (2) The stage at which the inflorescence expands the boot.
BRACE-ROOT	An aerial root that functions to brace the plant as in corn.
BROADCAST	To sow or scatter seed on the surface of the land by hand or by machinery.
BUD	An unexpanded flower or a rudimentary leaf, stem, or branch.
C HORIZON	The layer of weathered parent rock material below the B horizon of the soil but above the unweathered rock.
CALYX	The outer part of the perianth, composed of sepals.
CAMBIUM	The growing layer of the stem.
CARYOPSIS	The grain or fruit of grasses including the cereals.
CELLULOSE	Primary cell wall substance. A carbohydrate having the general formula $(C_6H_{10}O_5)n$.
CEREAL	A grass cultivated for its edible seeds or grains.

CHLOROPHYLL	The green coloring matter of plants which takes part in the process of photosynthesis. It occurs in the chloroplasts of the plant cell.
CHLOROSIS	Yellowing or blanching of leaves and other chlorophyll-bearing plant parts.
CLAY	Small mineral soil particles less than 0.002 mm. in diameter (formerly less than 0.005 mm.).
COLEOPTILE	The sheath covering the first leaf of a grass seedling as it emerges from the soil.
COLLAR	The area on the outer side of the leaf at the junction of the sheath and blade.
COROLLA	Inner part of the perianth, composed of petals.
COTYLEDONS	The first leaves of a plant as found in the embryo. The major portion of the two halves of a pea or bean (legume) seed.
COVER CROP	A crop grown between orchard trees or on fields between cropping seasons to protect the land from leaching and erosion.
CROSS-FERTILIZATION OR CROSS-POLLINATION	Fertilization secured by pollen from another plant.
CROWN	The base of the stems where roots arise.
CULM	The jointed stem of grasses.
DECIDUOUS	Falling away (shedding) of leaves or awns.
DEHISCENCE	Opening of valves or anthers, or separation of parts of plants.
DICOTYLEDONOUS	Plants producing two cotyledons in each fruit.
DIOECIOUS	Having stamens and pistils in separate flowers upon different plants.

DRILL	(1) A machine for sowing seeds in furrows. (2) To sow in furrows.
ENSILAGE	Silage
EXOTIC PLANT	An introduced plant not fully naturalized or acclimated.
FERTILE (PLANT)	Capable of producing fruit.
FERTILITY (SOIL)	The ability of the soil to provide the proper compounds in the proper amounts and in the proper balance for the growth of specified plants under the suitable environment.
FERTILIZATION (PLANT)	The union of the male (pollen) nucleus with the female (egg) cell.
FERTILIZATION (SOIL)	The application to the soil of elements or compounds that aid in the nutrition of plants.
FIBROUS ROOT	A slender threadlike root as in grasses.
FILAMENT	The stalk of the stamen which bears the anther.
FLOAT	(1) A land leveller. (2) A plank clod masher.
FLORET	Lemma and palea with included flower (stamens, pistil, and lodicules).
FODDER	Maize, sorghum, or other coarse grasses harvested whole and cured in an erect position. Pulled fodder is the leaves of corn or sorghum stripped by hand from the standing stalk and then cured. Topped fodder is the top of the maize stalk above the ear cut off and cured.
FORAGE	Vegetable matter, fresh or preserved, gathered and fed to animals.
FRIABLE	Easily crumbled in the fingers; nonplastic.

FUNGUS	A group of the lower plants that causes most plant diseases. The group includes the molds and belongs to the Phylum Thallophyta. Fungi reproduce by spores instead of seeds, contain no chlorophyll, and thus live on dead or living organic matter.
GLUMES	The pair of bracts at the base of a spikelet.
GRAIN	(1) A caryopsis. (2) A collective term for the cereals. (3) Cereal seeds in bulk.
GREEN MANURE	Any crop or plant grown and plowed under to improve the soil, especially by addition of organic matter.
HARDPAN	A hardened or cemented soil horizon.
HAY	The herbage of grasses or comparatively fine-stemmed plants cut and cured for forage.
HETEROZYGOUS	Containing two unlike genes of an allelomorphic pair in the corresponding loci (positions) of a pair of chromosomes. The progeny of a heterozygous plant does not breed true.
HILUM	The scar of the seed; its place of attachment.
HORIZON, SOIL	A layer of soil approximately parallel to the land surface with more or less well-defined characteristics.
HULL	(1) A glume, lemma, palea, pod, or other organ enclosing a seed or fruit. (2) To remove hulls from a seed.
HUMUS	The well-decomposed, more or less stable part of the organic matter of the soil.
HUSK	(1) The coarse outer envelope of a fruit, as the glumes of an ear of maize. (2) To remove the husks.
HYBRIDIZATION	The process of crossing organisms of unlike heredity.
IMPERFECT	Flower lacking either stamens or pistils.

INDETERMINATE INFLORESCENCE	Flowers arise laterally and successively as floral axis elongates.
INFLORESCENCE	The flowering part of the plant.
INTERNODE	The part of the stem or branch between two nodes.
JOINT	(1) A node. (2) The internode of an articulate rachis. (3) To develop distinct nodes and internodes in a grass culm.
LAND PLANE	A large, wheeled machine used to level the land.
LEAF	The lateral organ of a stem.
LEGUME	(1) Any plant of the family Leguminoseae. (2) The pod of a leguminous plant.
LEMMA	The outer (lower) bract of a grass spikelet enclosing the caryopsis.
LIME	Calcium oxide or quicklime (CaO), but often refers also to calcium carbonate ($CaCO_3$) and to calcium hydroxide or hydrated or slaked lime [$Ca(OH)_2$].
LODICULE	The organs at the base of the ovary of a grass floret that swell and force open the lemma and palea during anthesis.
MONOCOTYLEDON	Plant having one cotyledon as in the grasses.
MONOECIOUS	With stamens and pistils in separate flowers on the same plant.
NITRIFICATION	Formation of nitrates from ammonia.
NITROGEN FIXATION	The conversion of atmospheric (free) nitrogen to nitrogen compounds, chemically, or by soil organisms, or by organisms living in the roots of legumes.
NODE	The joint of a culm where a leaf is attached.

NUTRIENT (PLANT)	A chemical element taken into a plant that is essential to its growth, development, or reproduction.
OUTCROSS	A cross to an individual not closely related.
OVARY	Seed case of the pistil.
PALEA (PALET)	Inner (upper) bract of a floret in grasses lying next to the caryopsis. It usually is thin and papery.
PARTHENOGENESIS	The development of a new individual from a germ cell without fertilization.
PEDICEL	A branch of an inflorescence supporting one or more flowers. The stalk of a spikelet.
PEDUNCLE	The top section of the stalk that supports a head or panicle.
PERENNIAL	Living more than one year but may produce seed the first year.
PERFECT FLOWER	Having both pistil and stamens.
PETAL	A division of the corolla.
PETIOLE	The stalk of a leaf.
PHLOEM	Portion of a vascular bundle containing the sieve tubes through which are transported the food materials manufactured in the plant leaves.
PISTIL	The seed-bearing organ of a flower consisting of the ovary, style, and stigma.
PLANT	(1) Any organism belonging to the plant or vegetable kingdom. (2) To set plants or sow seeds.
PRODUCTIVITY (OF SOIL)	The capability of a soil for producing a specified plant or sequence of plants under a specified system of management.
PUBESCENT	Covered with fine, soft, short hairs.

PULSE	Leguminous plants or their seeds, chiefly those with large seeds used for food.
RACEME	An inflorescence in which the pediceled flowers are arranged on a rachis or axis.
RACHILLA (LITTLE RACHIS)	The axis of a spikelet in grasses.
RACHIS	The axis of a spike or raceme.
ROGUE	(1) A variation from the type of a variety or standard, usually inferior. (2) To eliminate such inferior individuals.
ROOT	The part of the plant (usually subterranean) which lacks nodes.
ROOTCAP	A mass of cells protecting the tip of a root.
ROOTHAIR	A single-celled protrusion of an epidermal cell of a young root.
SALINE SOIL	A soil containing an excess of soluble salts, more than approximately 0.2 percent but with a pH less than 8.5.
SAND	Small rock or mineral fragments having diameters ranging from 1 to 0.05 mm.
SECONDARY ROOT	A branch or division of a main root.
SEED	(1) The ripened ovule, enclosing a rudimentary plant and food necessary for its germination. (2) To produce seed (a plant). (3) To sow.
SEEDLING	(1) The juvenile stage of a plant grown from seed. (2) A plant derived from seed (in plant breeding).
SEMINAL ROOT	A root arising from the base of the hypocotyl.
SHOOT	(1) A stem with its attached members. (2) To produce shoots. (3) To put forth.

SILAGE	Forage preserved in a succulent condition by partial fermentation in a tight container.
SILT	Small mineral soil particles of a diameter of 0.05 to 0.002 mm. (formerly 0.05 to 0.005 mm.).
SOIL	The natural medium for the growth of land plants on the surface of the earth, composed of organic and mineral materials.
SOW	To place seeds in a position for growing.
SPIKE	An unbranched inflorescence in which the spikelets are sessile on the rachis, as in wheat and barley.
SPIKELET	The unit of inflorescence in grasses, consisting of two glumes and one or more florets.
SPROUT	(1) A young shoot. (2) To produce sprouts. (3) To put forth sprouts from seeds. (4) To remove sprouts as from potato tubers.
STAMEN	The pollen-bearing organ of a flower.
STIGMA	The part of the pistil that receives the pollen.
STOLON	A modified propagating creeping stem above ground that produces roots.
STOMA	An opening in the epidermis for the passage of gases and water vapor.
STOMATA	Plural of stoma.
STOOL	The aggregate of a stem and its attached tiller, i.e., a clump of young stems arising from a single plant.
TAPROOT	A single central root.
TASSEL	(1) The staminate inflorescence of maize composed of panicled spikes. (2) To produce tassels.
TILTH	The physical condition of the soil with respect to its fitness for the planting or growth of a crop.

TRANSPIRATION	The evaporation of moisture through the leaves.
TUBER	A short thickened subterranean branch.
UNISEXUAL	Flower containing either stamens or pistils but not both.
WEED	A plant that in its location is more harmful than beneficial.
WINTER ANNUAL	A plant that germinates in the fall, and blooms in the following spring or summer.
XYLEM	Woody part of fibrovascular bundle containing vessels; the water-conducting tissue.

GPO 893-148

Since 1961 when the Peace Corps was created, more than 80,000 U.S. citizens have served as Volunteers in developing countries, living and working among the people of the Third World as colleagues and co-workers. Today 6000 PCVs are involved in programs designed to help strengthen local capacity to address such fundamental concerns as food production, water supply, energy development, nutrition and health education and reforestation.

Loret Miller Ruppe, Director
Edward Curran, Deputy Director Designate
Richard B. Abell, Director, Office of Program Development

Peace Corps overseas offices:

BELIZE
P.O. Box 487
Belize City

BENIN
BP 971
Cotonou

BOTSWANA
P.O. Box 93
Gaborone

CAMEROON
BP 817
Yaounde

CENTRAL AFRICAN REPUBLIC
BP 1080
Bangui

COSTA RICA
Apartado Postal 1266
San Jose

DOMINICAN REPUBLIC
Apartado Postal 1414
Santo Domingo

EASTERN CARRIBBEAN
Including: Antigua Barbados, Grenada, Montserrat, St. Kitts-Nevis, St.Lucia, St. Vincent, Dominica
"Erin Court"
Bishops Court Hill
P.O. Box 696-C
Bridgetown, Barbados

ECUADOR
Casilla 635-A
Quito

FIJI
P.O. Box 1094
Suva

GABON
BP 2098
Libreville

GAMBIA, The
P.O. Box 582
Banjul

GHANA
P.O. Box 5796
Accra (North)

GUATEMALA
6a Avenida 1-46
Zona 2
Guatemala

HONDURAS
Apartado Postal C-51
Tegucigalpa

JAMAICA
9 Musgrove Avenue
Kingston 10

KENYA
P.O. Box 30518
Nairobi

LESOTHO
P.O. Box 554
Maseru

LIBERIA
Box 707
Monrovia

MALAWI
Box 208
Lilongwe

MALAYSIA
177 Jalan Raja Muda
Kuala Lumpur

MALI
BP 85
Bamako

MAURITANIA
BP 222
Nouakchott

MICRONESIA
P.O. Box 336
Saipan, Mariana Islands

MOROCCO
1, Zanquat Benzerte
Rabat

NEPAL
P.O. Box 613
Kathmandu

NIGER
BP 10537
Niamey

OMAN
P.O. Box 966
Muscat

PAPUA NEW GUINEA
P.O. Box 1790
Boroko

PARAGUAY
c/o American Embassy
Asuncion

PHILIPPINES
P.O. Box 7013
Manila

RWANDA
c/o American Embassy
Kigali

SENEGAL
BP 2534
Dakar

SEYCHELLES
Box 564
Victoria

SIERRA LEONE
Private Mail Bag
Freetown

SOLOMON ISLANDS
P.O. Box 547
Honiara

SWAZILAND
P.O. Box 362
Mbabane

TANZANIA
Box 9123
Dar es Salaam

THAILAND
42 Soi Somprasong 2
Petchburi Road
Bangkok 4

TOGO
BP 3194
Lome

TONGA
BP 147
Nuku'Alofa

TUNISIA
B.P. 96
1002 Tunis-Belvedere
Tunis

UPPER VOLTA
BP 537-Samandin
Ouagadougou

WESTERN SAMOA
P.O. Box 880
Apia

YEMEN
P.O. Box 1151
Sana'a

ZAIRE
BP 697
Kinshasa