Centro Internacional de Agricultura Tropical

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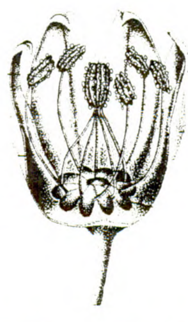
Morphology of the Cassava Plant



STUDY GUIDE

TO BE USED AS A SUPPLEMENT TO THE AUDIOTUTORIAL UNIT ON THE SAME TOPIC

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Morphology of the Cassava Plant

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Contents

Objectives

This audiotutorial unit has the fundamental objective of describing each part of the cassava plant and explaining its characteristics.

This objective will be achieved if one is able to:

1. **Give the taxonomic classification of cassava beginning with its class.**

2. **Identify by their botanical names the parts of the leaf, the inflorescence, the fruit, the seed, the stem, and the root system of the cassava plant.**

3. **Identify the various possible structural arrangements of the cassava inflorescence.**

4. **Distinguish a female flower from a male one in a cassava inflorescence and describe the differences enabling one to make this distinction.**

5. **Distinguish the types of branching that the stem can produce.**

6. **Differentiate the types of tuberous roots by their shape.**

7. **Explain the differences between cultivars of sweet and bitter cassava in regard to their hydrocyanic acid content.**

Introduction

Cassava is one of the principal useful tropical plants and is found on all continents. There are different opinions about the center of origin of this species. However, the majority of botanists and ecologists consider the northeast of Brazil to be the most probable center of origin. The greatest diversity of the genus *Manihot* is found in Brazil, southwestern Mexico, and Guatemala.

Evidence indicates that the area of domestication of cassava comprises and extensive geographic region from southern Brazil to Mexico; cassava has been cultivated in that zone for approximately 5000 years. Archaeological studies indicate that cassava was cultivated 4000 years ago in Peru by ancient pre-Incan civilizations.

The distribution of cassava to other continents began after the discovery of America. The Protuguese took it from Brazil to the western coast of Africa in the 15th Century; later, at the end of the 18th Century, they introduced it to Madagascar and them onto the east coast of Africa. The fact that cassava was introduced in Africa through both coasts explains the wide diversity of this species on that continent.

Cassava was introduced in southeastern Asia by Spanish merchants at the beginning of the 17th Century. Finally, about 1800, cassava passed from Africa to India, where it is widely distributed and is important in nutrition.

Currently, cassava is a crop of great importance in all tropical regions of the world, not only for the consumption of fresh roots as a subsistence crop but also for its agroindustrial use.

1. Taxonomy

Within the systematic hierarchy, cassava belong to the class Dicotyledoneae, characterized by the production of seed with two cotyledons; to the subclass Archichlamydeae, which is differentiated by the little-evolved perianth; to the order Euphorbiables, family Euphorbiaceae, tribe Manihotae, genus Manihot and species *Manihot esculenta* Crantz (Table 1).

It can be said that the order Euphorbiales is best represented by the great Euphorbiaceae family, made up of some 7200 species. The Euphorbiaceae are characterized principally by the notable development of laticiferous vessels, composed of secretory cells called galactocytes.

Within the Euphorbiaceae family are plants with very different growth habits, including trees, shrubs, and grasses, and of diverse economic importance; some produce latex (*Hevea brasilensis*), others produce oil (*Ricinus comunis*), or edible roots (*Manihot* spp.), and some behave as weeds (*Euphorbia* spp.). There are also ornamental and medicinal Euphorbiaceae.

Table 1. *Taxonomic classification of cassava.*

Class:	Dicotyledoneae
Subclass:	Archichlamydeae
Order:	Euphorbiales
Family:	Euphorbiaceae
Tribe:	Manihoteae
Genus:	Manihot
Species:	*Manihot esculenta* Crantz

In the varied floral group of the Euphorbiacea, different types of inflorescences are found: raceme, panicle, and cyathium types are the principal ones (Figure 1). The flowers are unisexual and the fruit is trilocular (Figure 2).

One of the most important tribes of the Euphorbiaceae family is Manihotae, represented by the genus *Manihot*. The plants in this genus are shrub types or tall grasses.

About 100 species have been classified within the genus *Manihot*; the only one that is cultivated commercially is *Manihot esculenta* (Crantz), whose synonyms are *Manihot utilissima*, *Manihot edulis*, and *Manihot aipi*. It is known commonly as yuca, mandioca, cassava, manioc, manioca, tapioca, mhogo, and omowgo.

Cassava is a monoecious, bushy with sympodial branching; its height varies from 1 to 5 meters, depending on the cultivar and ecological conditions. Plants between 1 and 3 meters tall are most common.

Within this species are bitter and sweet varieties, depending upon how much hydrocyanic acid they contain. The number of chromosomes in the species is 2N = 36.

The wide variability of the botanical characteristics of *M. esculenta* indicates a high degree of intraspecific hybridization. Thus, there are numerous cultivars of the species which are distinguished by morphological characteristics such as plant height; size, shape, and color of leaves; size, shape, and color of roots; etc.

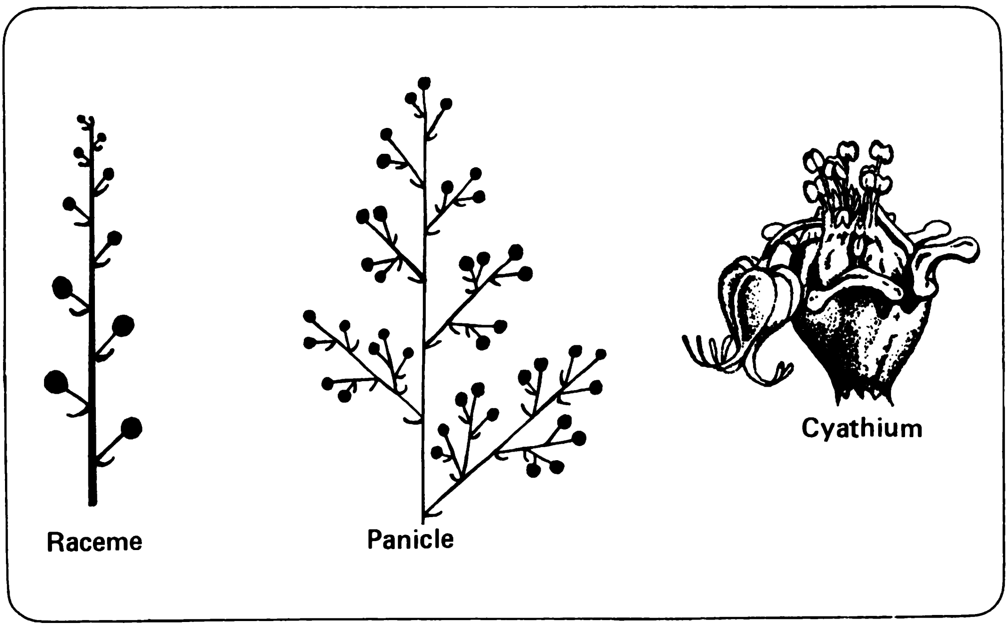


Figure 1. *Types of inflorescences founded in the Euphorbiaceae family.*

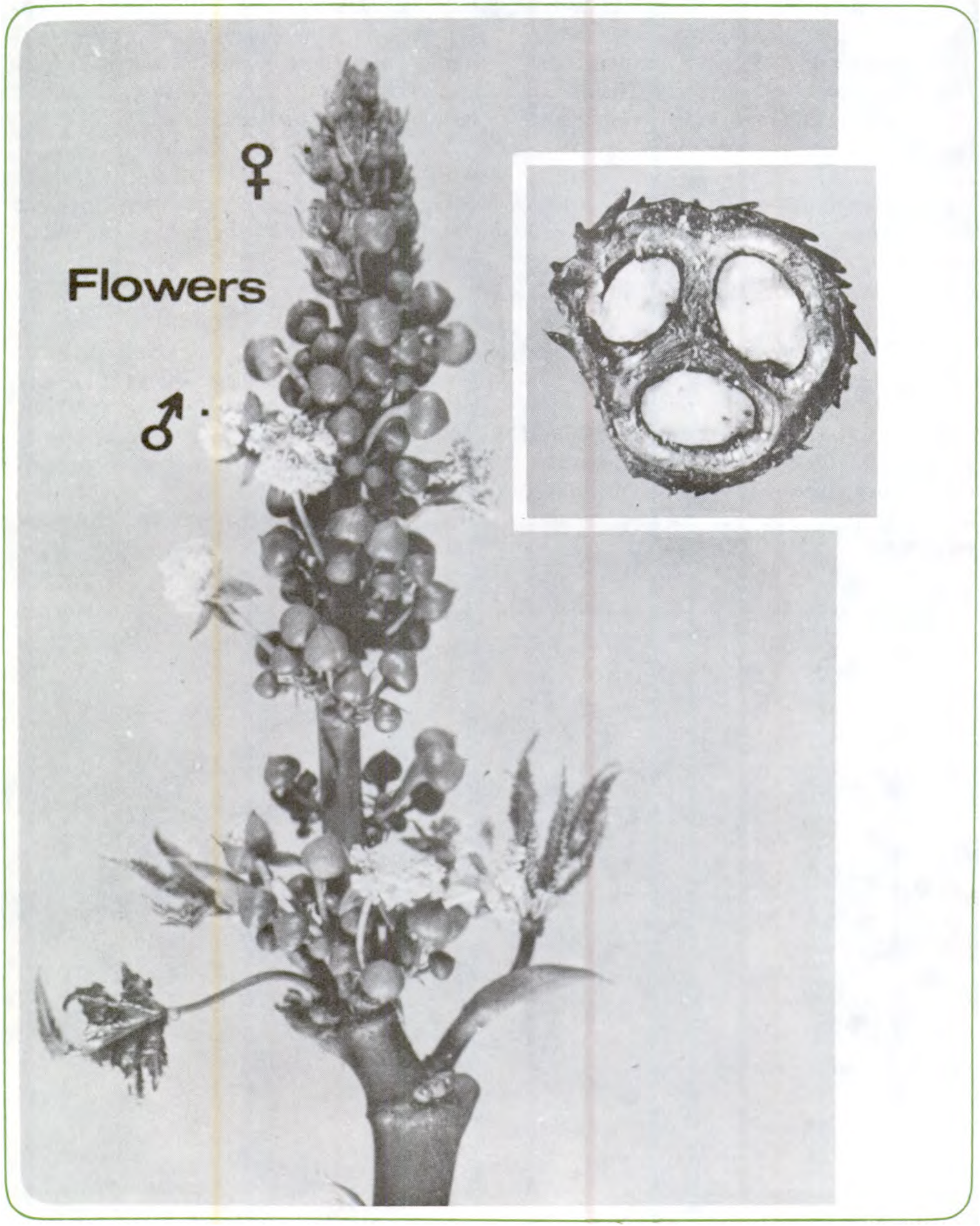


Figure 2. *In the Euphorbiaceae family the flowers are unisexual and the fruit is trilocular.*

2. Morphological Description

The principal objective of this unit is to present the morphology of cassava, or describe the diverse organs that make up the cassava plant. Study of the morphology is done through characteristics, that is, the distinctive external features of each organ that are visible on both macro-and microscopic scales. A detailed examination of each organ facilitates general study but the observer must understand how all organs function together in the total plant.

Morphological characteristics of the plant are grouped as either constant or variable characteristics; the constant are those typifying the taxon, that is, the species or variety. The variable characteristics are influenced by environmental conditions and can be considered as products of the action of the environment on the genotype.

It is difficult to precisely describe the morphological characteristics of cassava because of the great number of genotypes and the diversity of ecological environments in which cassava is commercially grown. Hence, the action of the environment on the genotype (variety) is always important.

The morphology of the cassava plant will be described in the following order:

- Leaves
- Inflorescence
    - Male flower
    - Female flower
- Fruit
- Seed
- Stems
- Root system

2.1 Leaves

As in other plants, the cassava plant's leaves are the organs in which photosynthesis transform the sun's radiant energy into chemical energy. The total number of leaves produced, their longevity, and production rate are all varietal characteristics that vary with environmental conditions.

Leaf formation in cassava plants starts from the axillary meristems located at the nodes of the stem; leaves are alternate and have a phyllotactic index of 2/5. This phyllotactic index indicates that leaves 1 and 6 are in identical positions as viewed around the stem or are orthostichous; beginning with leaf 1 there are two revolutions around the stem to reach leaf 6, with the upper leaf situated in the same orthostichy as leaf 1. There are five successive intermediate leaves, not counting leaf 1 (Figure 3).

The simple leaves consist of the foliar lamina and the petiole. The foliar lamina is palmate and lobate. Completely developed leaves are in different colors, depending on the cultivar; the basic colors are purple, dark green, and light green.

There is generally an uneven number of lobes, ranging from 3 to 9, but this characteristic varies with the variety. The number of lobes can also differ among leaves of the same plant. Lobes are from 4 to 20 cm long and from 1 to 6 cm wide. Central lobes are larger than the lateral ones.

Basic designations have been adopted at CIAT to identify the shape of the lobes: linear or straight, arched, and pandurate. However, other institutions have a broader classification that also includes elliptic, lanceolate, and obovate-lanceolate shapes (Figure 4).

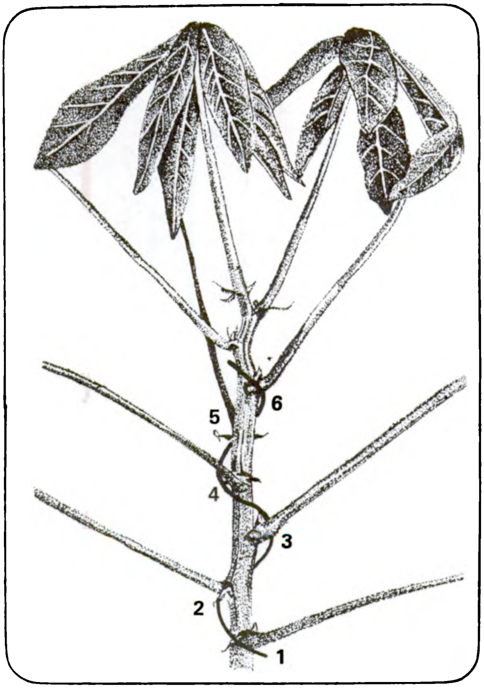


Figure 3. *Arrangement of the leaves on the stem of the cassava plant (Phyllotaxy 2/5).*

There are marked differences in leaf size among the different varieties, and the size varies with the age of the plant. The leaves produced during the fourth month after planting are those that become the largest (Figure 5).

Completely developed leaves are glabrous, that is, they are smooth and lack pubescence. The upper leaf surface is covered with a shiny, waxy epidermis; most of the stomata are located on the opaque underside of the leaf. However, some varieties also have a significant number of stomata on the upper leaf surface.

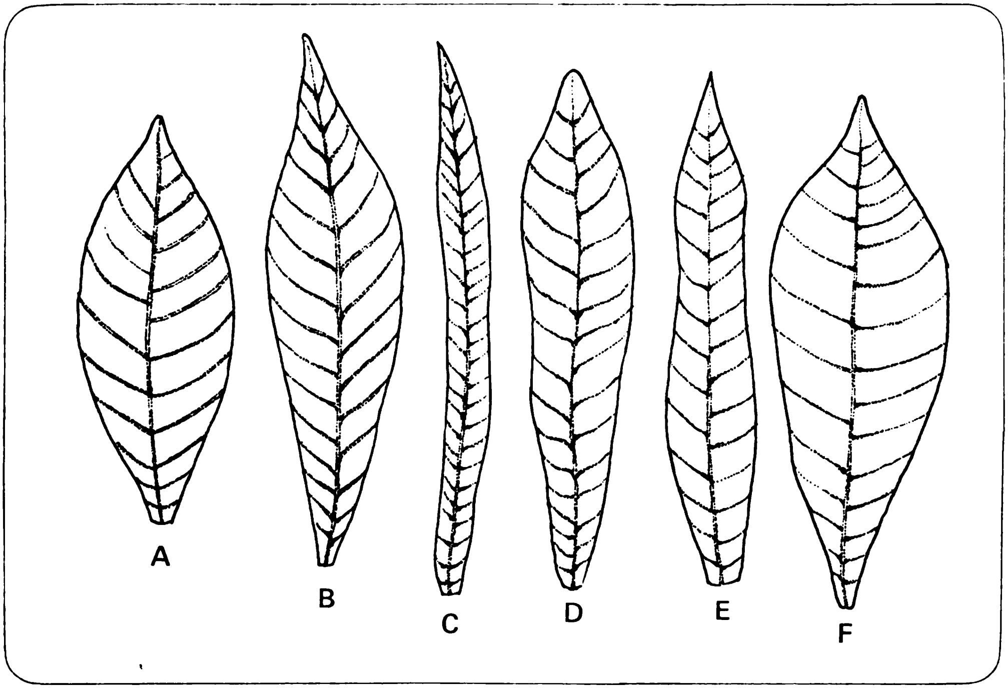
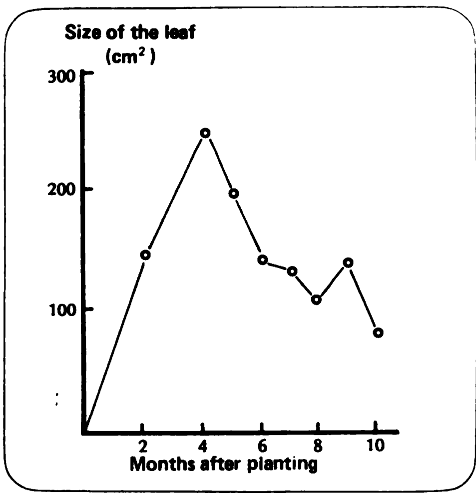


Figure 4. *Shapes of cassava leaf lobes: (A) elliptic, (B) lanceolate, (C) straight or linear, (D) obovate-lanceolate, (E) pandurate, and (F) arched (taken from: Catalogo de la colección de yuca **Manihot esculenta** (Crantz) del CATIE, 1980.*



The color of the veins can vary from green to purple and is another varietal characteristic. Vein color can be the same or different on the two sides of the leaf.

The leaf petiols, whose length varies between 9 and 20 cm, are thin and of different pigmentation, from green (no pigmentation) to purple (intense pigmentation). The color of the petiole is not always the same as that of the veins.

Figure 5. *Size of leaves of the variety M Col-72 at different ages of the plant.*

Each leaf is surrounded by two stipules approximately 0.5 to 1 cm in lenght, which remain or are not attached to the stem when the leaf is completely developed (Figure 6).

2.2 Inflorescence

Not all cassava varieties flower, and among those that do, there are great differences in the time of flowering and the number of flowers produced. As with all plants of the genus *Manihot*, cassava is a monoecious plant, having male and female flowers on the same plant.

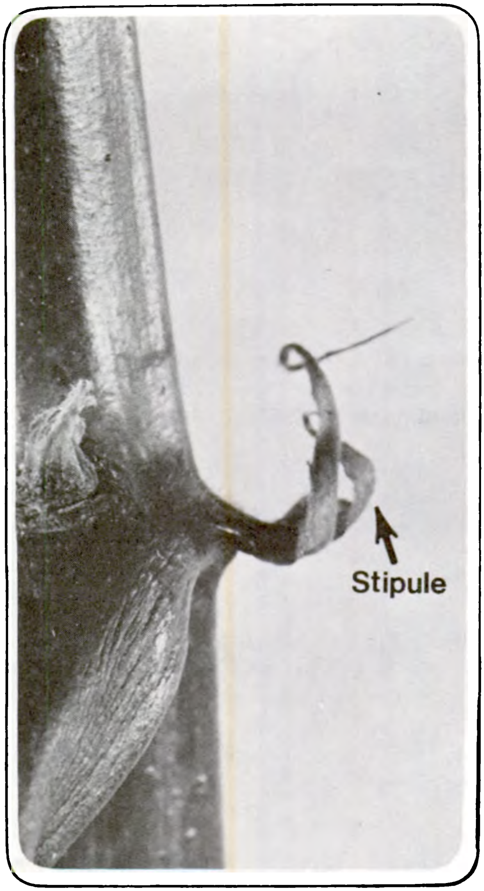


Figure 6. *Stipule.*

Normally, cross pollination occurs in cassava and is basically accomplished by insects. Cassava is, therefore, a highly heterozygous plant.

On the same inflorescence, the female, flowers open one or two weeks before the male ones, and are said to be protogynous. Male and female flowers on different branches of the same plant can open at the same time.

Cassava shows considerable variation in the structural arrangements of the inflorescence. The two basic units, the raceme and the panicle, combine to produce several forms (Figure 7).

1. A group of racemes.

2. Groups of racemes and/or panicles that surround a central panicle. Generally the central panicle is the most prominent.

The inflorescence is generally formed at the insertion point of the reproductive branchings; one can also find inflorescences formed in the leaf axils on the upper part of the plant (Figure 8).

Female flowers are commonly located on the lower part of the branches or the panicles; male flowers are grouped on the upper part of the inflorescence (Figure 9).

When the inflorescence has a central panicle, almost all of the flowers are male; the few female flowers are located on the lower part of the panicle. In some cases the central panicle is comprised only of male flowers.

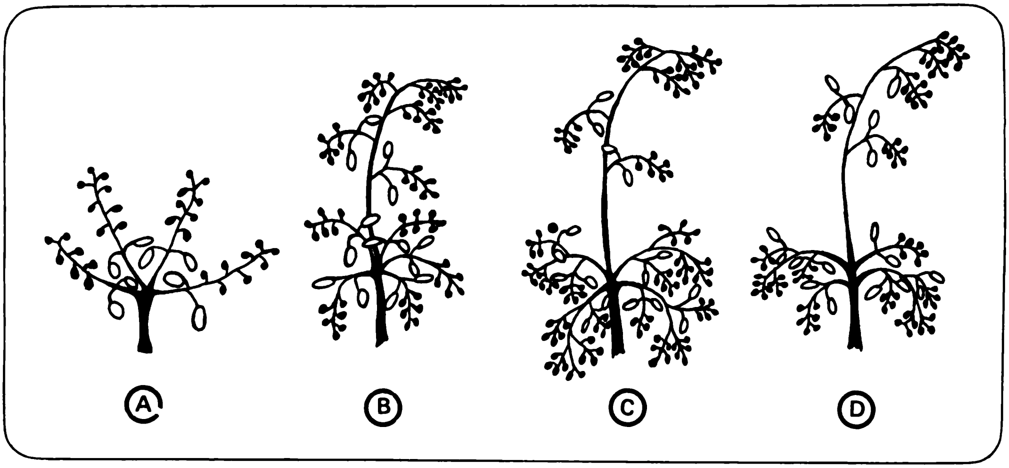


Figure 7. *Structural arrangements of cassava inflorescences (A) group of racemes, (B) group of racemes surrounding a central panicle, (C) group of panicles surrounding a central panicle, (D) group of racemes and panicles surrounding a central panicle.*

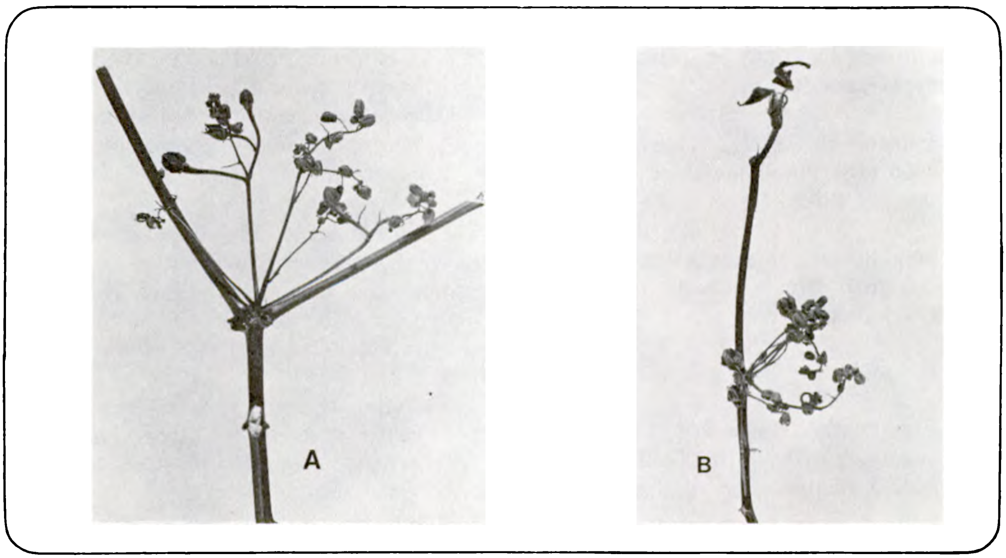


Figure 8. *(A) Inflorescence formed at the point of insertion of the reproductive branchings. (B) Inflorescence formed in the axil of a leaf.*

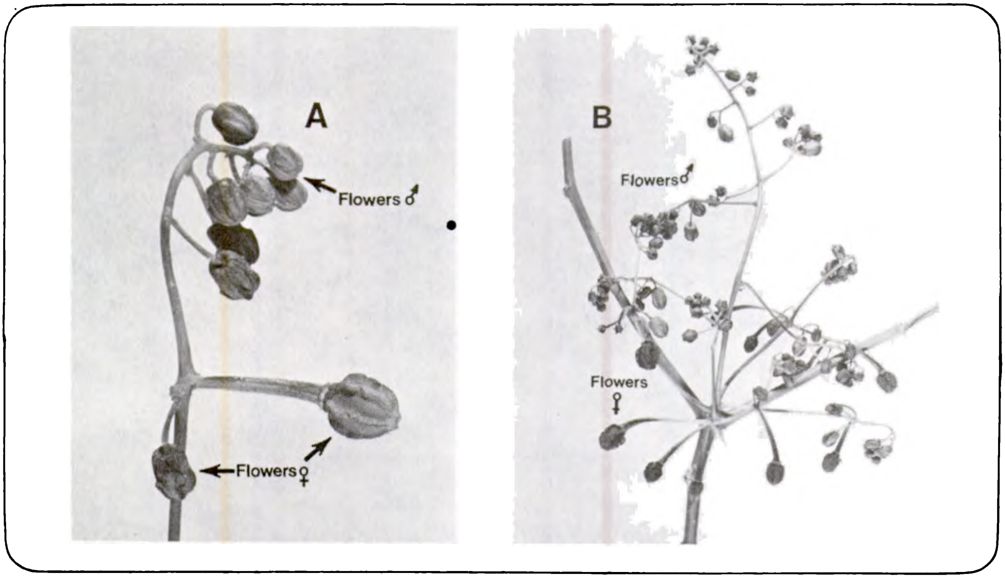


Figure 9. *Location of female and male flowers in (A) a raceme and (B) an inflorescence.*

The following parts can be distinguished on a raceme (Figure 10):

- Female flowers: arranged opposite each other; the number varies between one and three.
- Male flowers: smaller and more numerous than female flowers; arranged in alternate positions.
- Peduncle: the lower axis of the raceme.
- Floral rachis: upper axis of the raceme beginning with the first floral insertion; it is a continuation of the peduncle.
- Pedicel: cylindrical part that units the basal disk of a flower to the axis of the raceme.
- Each male or female flower has a primary bract and a bracteole, foliaceous organs present in the inflorescences; the organs remain or are not attached when the flowers are developed.

The panicle is considered botanically as a raceme of racemes, that is a principal raceme comprised of secondary racemes. The following parts can be distinguished on the panicle (Figure 11):

- Peduncle, rachis, primary bracts, pedicellar or secondary bracts, axes of the secondary racemes, pedicels, and flowers.

2.2.1 Male and female flowers

The flowers do not have a calyx or corolla,

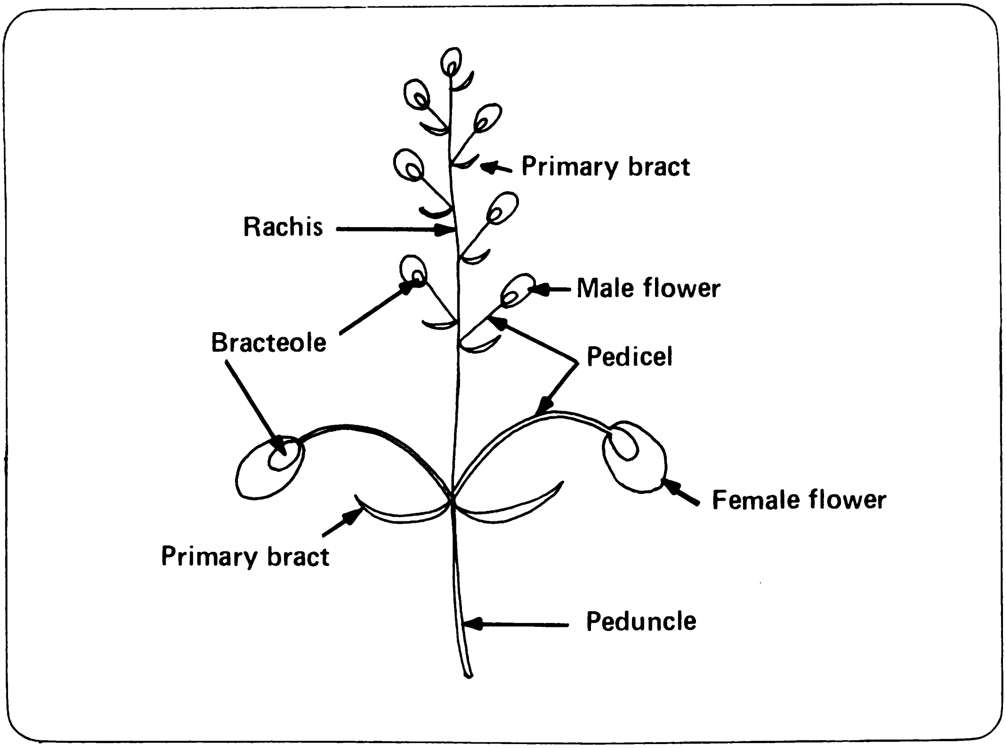


Figure 10. *Components of a raceme.*

but an indefinite structure called the perianth or perigonium, which is made up of five yellow, reddish or puple tepals; the tepals are separated down to the base in the female flower but not in the male flower.

The male flower, whose size is approximately half that of the female flower, has a thin, straight, and very short pedicel; the pedicel of the female flower is thick, curved, and long.

In the interior of the male flower is a basal disk divided into ten lobes. A rudimentary ovary can be observed in the center of the disk. Ten stamens originate from between the lobes of the basal disk. They are arranged in two whorls and support the anthers. The five external stamens are separate and longer than the inner ones; the inner stamens unite at the top to form a set of anthers. The anthers on the tops of the stamens are elongated and tilted toward the center of the flower (Figure 12A).

In the interior of the female flower is a basal disk that is less lobulated than that of the male flower; the disk rests on the central wall of the ovary. In some varieties there are staminodia arising from the glandular lobes

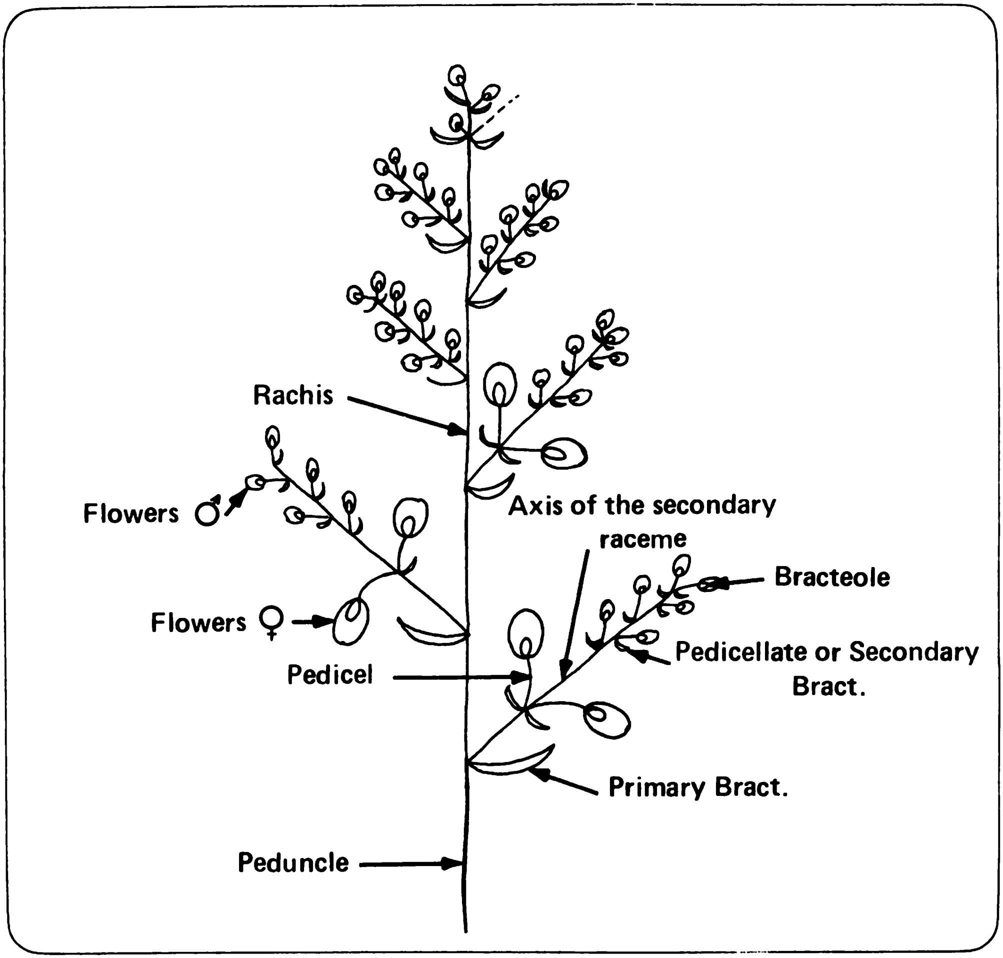


Figure 11. *Components of a panicle.*

of the basal disk. The superior ovary is divided into three locules, each containing an ovule. A very small style is located on top of the ovary; a stigma with three undulate and fleshy lobes originates from the style (Figure 12B).

In general, male flowers that have produced their pollen detach from the floral raceme, whereas the female flowers that have been fertilized remain on the plant to become fruit.

2.3 Fruit

After pollination and subsequent fertiliza-

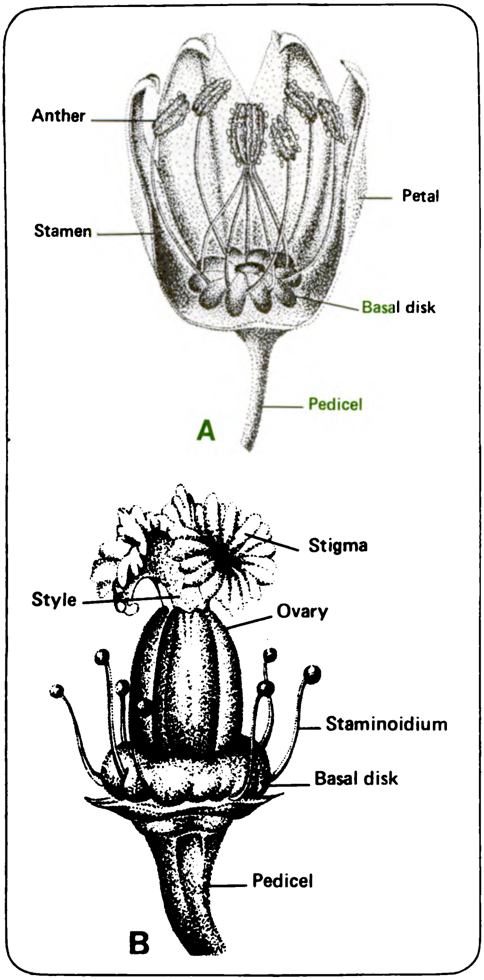


Figure 12. *Male (A) and female (B) flowers.*

tion, the ovary develops to form the fruit. Fruit maturation takes between three and five months.

The fruit is a dehiscent, trilocular capsule that is ovoid or globular in shape. It is from 1 to 1.5 cm in diameter and has six straight, prominent longitudinal ridges or aristae (Figure 13).

If the fruit is cut transversally, one can see a series of well-differentiated tissues: the epicarp, mesocarp, and endocarp (Figure 14).

The endocarp, which has a woody consistency, opens abruptly when the fruit is mature and dry in order to expel and disperse the seeds. The epicarp and the mesocarp wither when the seed is mature.

The dehiscence of the fruit of cassava is bicidal, that is, a combination of two types of dehiscence: septicidal and loculicidal.

Septicidal dehiscence is produced in the fruit when its dissepiments open along a parallel plane, dividing it in two (Figure 15A). This type does not usually occur alone; on the contrary, septicidal dehiscence occurs in combination with some other manner of fruit opening. In the case of cassava, loculicidal dehiscence occurs along with septicidal dehiscence.

In loculicidal dehiscence, the openings originate along the midveins of the carpels, which are destroyed by this type of dehiscence (Figure 15B).

With a combination of the two types of dehiscence (septicidal and loculicidal), the fruit opens into six valves (Figure 15C), as is the case with cassava.

2.4 Seed

The seed is the means of sexual reproduction of the plant. Consequently, it is of incalculable value in the genetic improvement of the crop.

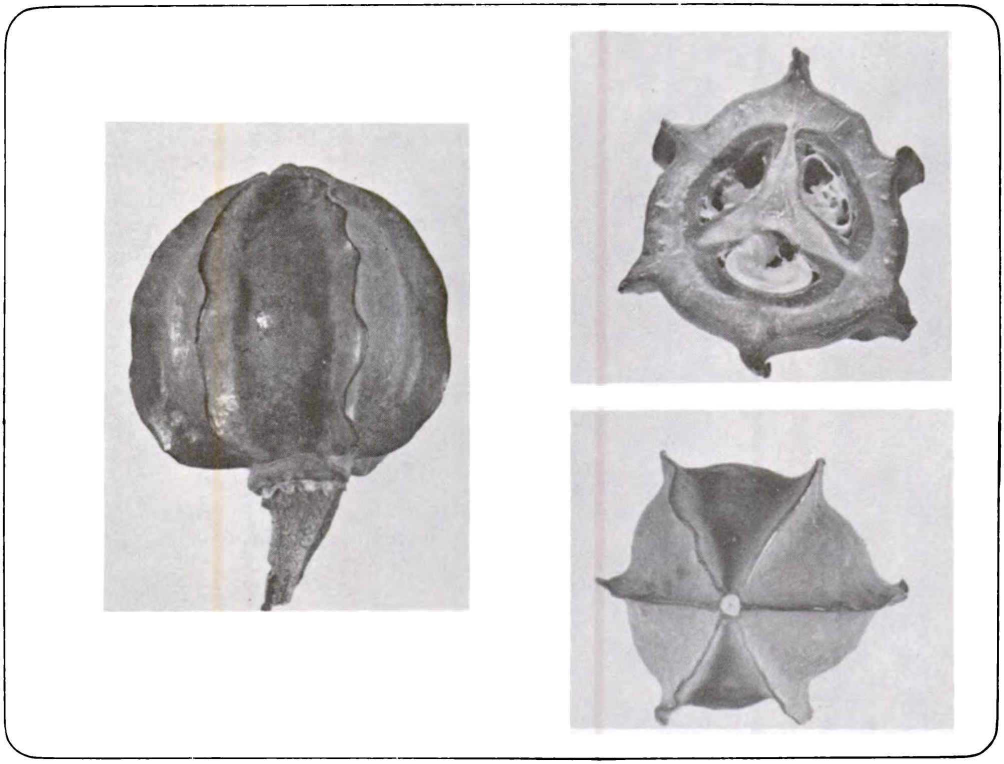


Figure 13. *Fruit.*

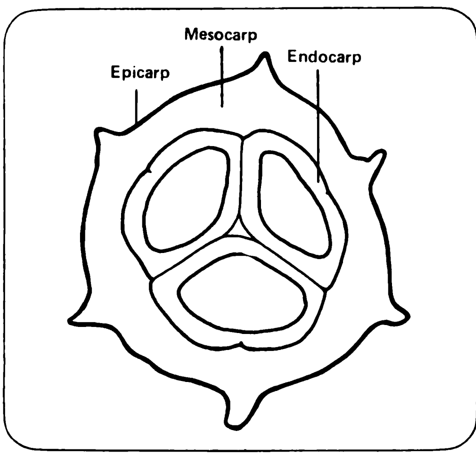


Figure 14. *Transversal section of cassava fruit showing its tissues.*

Cassava seed is ovoid-ellipsoidal in shape and is approximately 10 mm long, 6 mm wide and 4 mm thick. The smooth seed coat is dark brown, mottled with gray. On the upper part of the seed, especially new ones, is found the caruncle. This structure is lost after the seed falls to the ground. The seed ends in a small cavity at the end opposite the caruncle. A suture called a raphe extends from the caruncle and ends in the basal cavity (Figure 16).

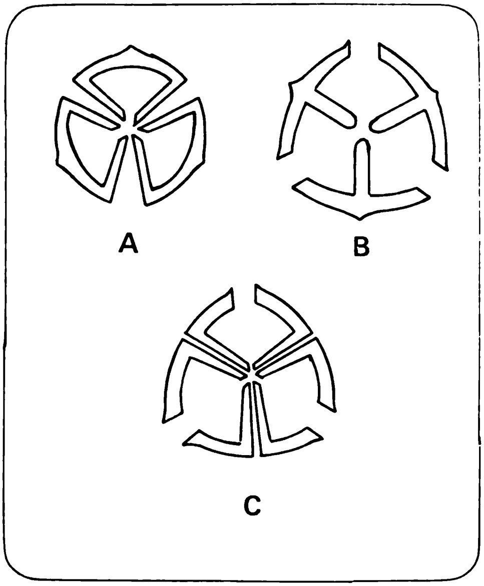


Figure 15. *Septicidal dehiscence (A); loculicidal dehiscence (B); and combination of septicidal and loculicidal dehiscence (C), the type of dehiscence of cassava fruit.*

Figure 17 shows the internal constituents of the seed across the transversal, longitudinal and ventral sections. The following seed parts are shown.

Testa: The external part of the seed.

Endosperm: Found inmediately under the testa and formed by parenchymatous polyhedral cells. Its function is to protect the embryo and provide it with nutrient reserves.

Cotyledons: They are foliaceous, white, elliptical and fleshy. The internal part of the cotyledons is in contact with the primary or cotyledonary leaves.

2.5 Stems

The stems are the means for asexual multiplication of the species; they serve as "seed" for commercial cassava production.

The mature stem is cylindrical, with a diameter varying from 2 to 6 cm; both the thickness and the color vary with the age of the plant and the variety. Mature stems ar of three

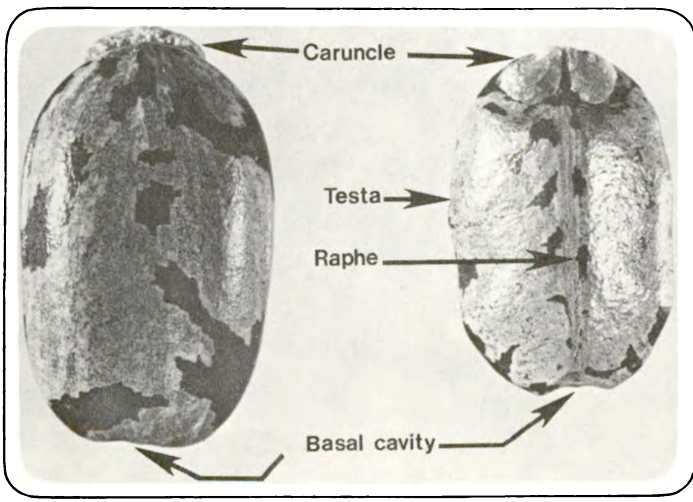


Figure 16. *Seed of cassava.*

basic colors: silver or gray, purple, and brown.

The stems are formed by alternating nodes and internodes. The node is the point at which a leaf joins the stem and the internode is that portion of the stem between two successive leaves. Inserted in the node is the leaf petiole, which is an axillary bud protected by a scale and two lateral stipules

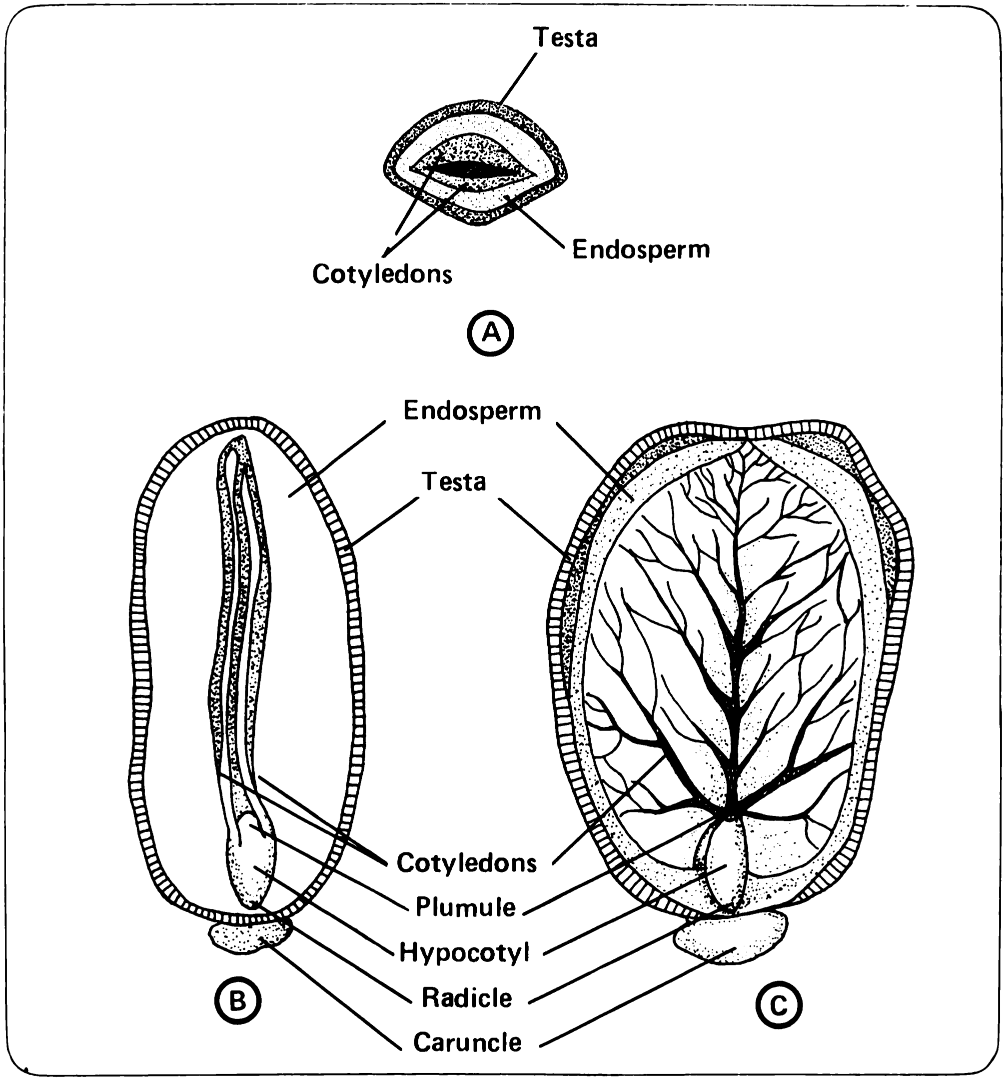


Figure 17. *Parts of the cassava seed as observed in: (A) transversal section, (B) longitudinal section, and (C) ventral section.*

(Figure 18). On the nodes of the oldest parts of the stem one can see protuberances that are the scars left by the plant's first leaves.

The length of the internodes on the main stem varies greatly because, in addition to the variety, other factors influence this characteristic. These factors include the age of the plant, drought, insect attack, etc.

A plant grown from vegetative material, that is, a cutting, can produce as many primary stems as there are viable buds on the cutting. In some varieties with strong apical dominance, only one stem develops (Figure 19). In addition to varietal differences, other factors that determine the number of primary stems are the size and condition of the cutting, and the position in which the cutting is planted.

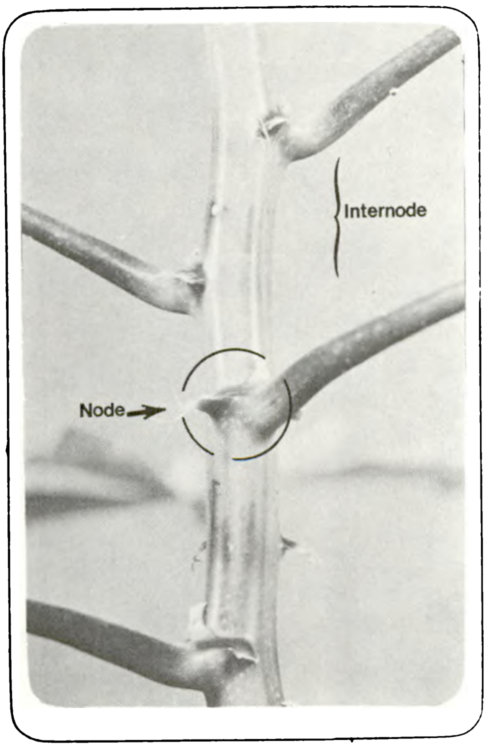


Figure 18. *Internode and node of the stem.*

The stem produces two types of branching: lateral branches and reproductive branches; the latter type constitutes the most stable varietal characteristic.

Reproductive branching:

Cassava is a plant with sympodial branching. The main stem or stems divide dichotomously, or tetrachotomously (Figure 20), thereby producing secondary branches. The secondary branches, in turn, produce other successive branchings. These branchings are induced by flowering and, therefore, have been called "reproductive branchings".

However, these branches develop whether or not an inflorescence is present. The time when these branchings are produced and the factors controlling the process still have not been totally determined.

The pattern of branching of the cassava plant varies in different cultivars. In some, for example, after the main stem has developed, it produces three braches simultaneously. Each of these branches also produces three branches simultaneously, and so on. In other cultivars, the branching pattern is not so regular.

Other important branching characteristics include the height of the initial branches and the angle formed between the first branches and the main stem. The latter characteristic determines the type of branching habit, which varies from decumbent or horizontal (±90°) to erect (25°) (Figure 21).

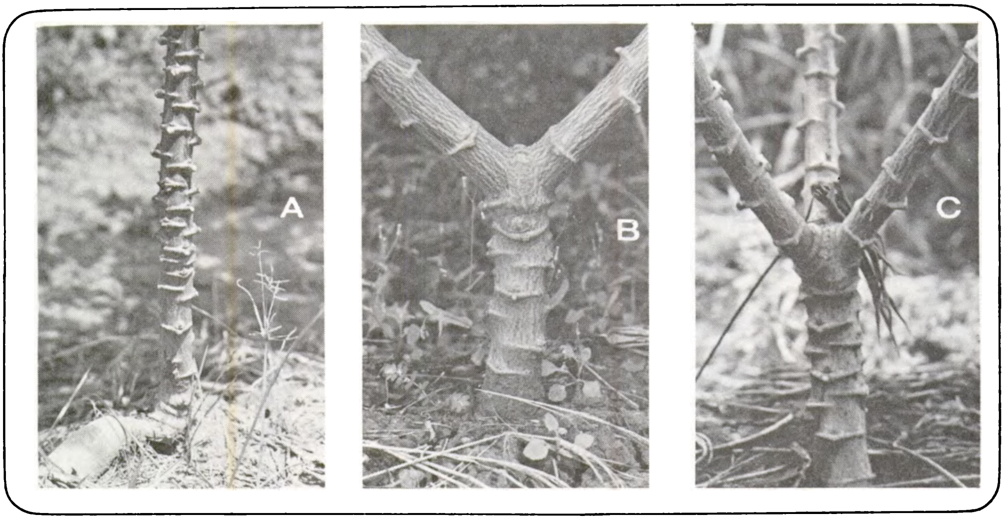


Figure 19. *Stems of adult plants originating from cuttings, which produce (A) one, (B) two, and (C) three primary stems.*

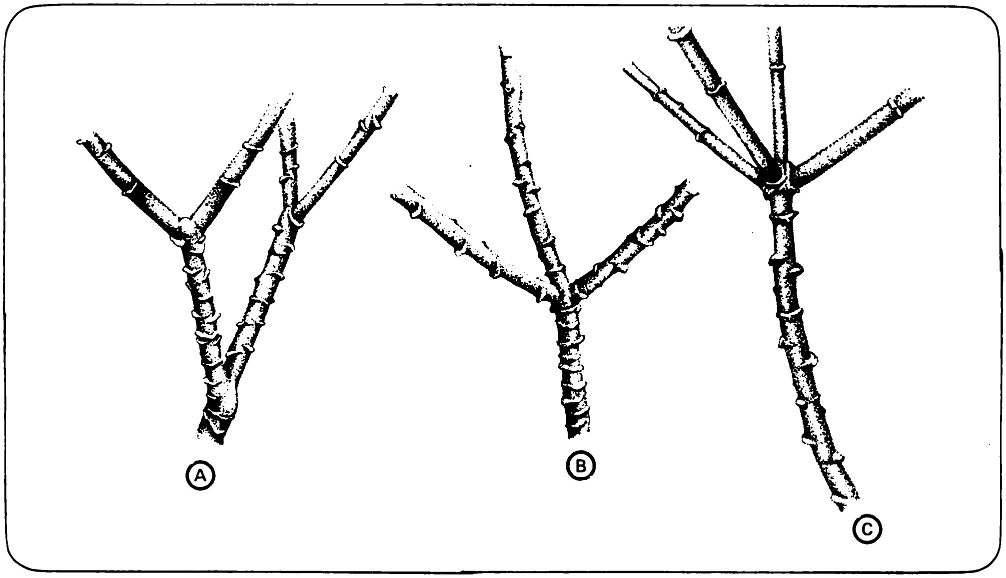


Figure 20. *Branching of the main stem; (A) dichotomous, (B) trichotomous, and (C) tetrachotomous.*

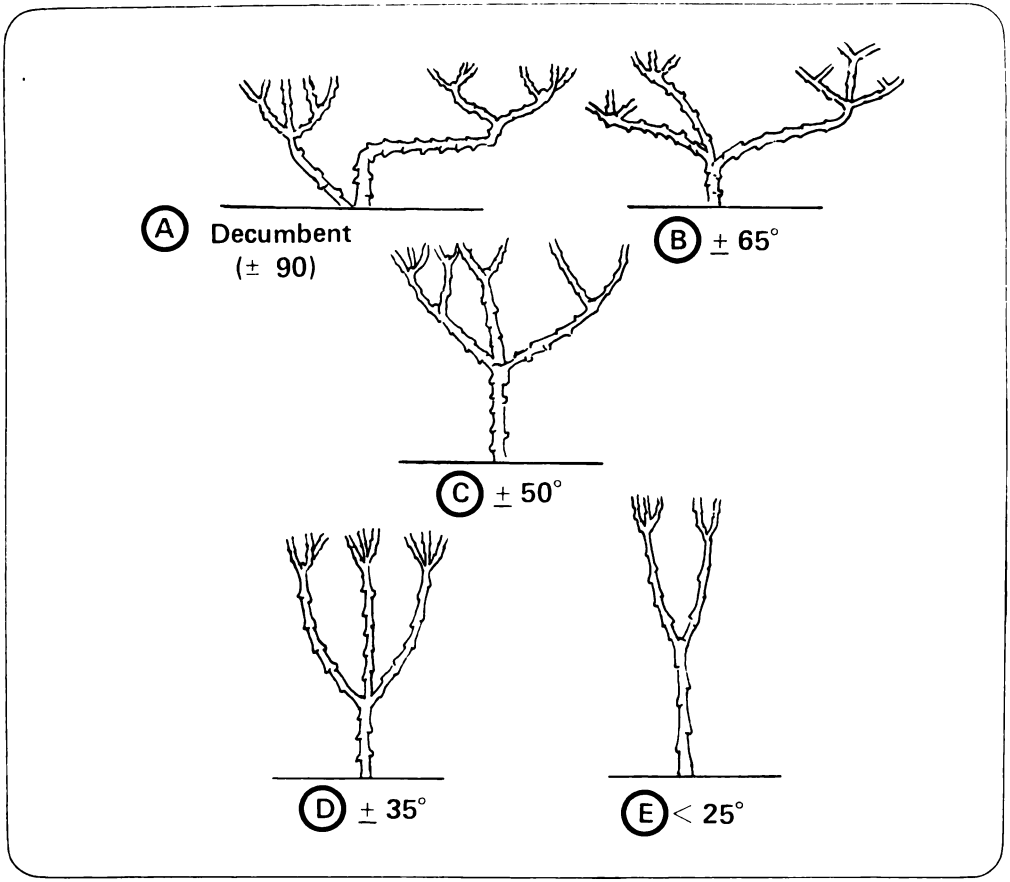


Figure 21. *Branching habits (taken from: Catalogo de la colección de yuca **Manihot esculenta** (Crantz) del CATIE, 1980).*

Lateral branching:

Lateral branchings are sporadic and depend on the number of plants/ha, climatic conditions, and the cultivar. They are branches or "suckers" from the axillary buds of the leaves of the main stem. Generally the branches are thinner than the main stem, with longer internodes and small leaves (Figure 22).

As a reaction to damage to the terminal buds caused by the shoot fly (*Silba pendula*) or by thrips, the axillary buds develop and produce branchings.

The internal structure of the stem of the cassava plant is typical of dicotyledonous plants. The first layer is the epidermis; beneath that is the cortex, followed by the

Figure 22. *Lateral branches or "suckers".*

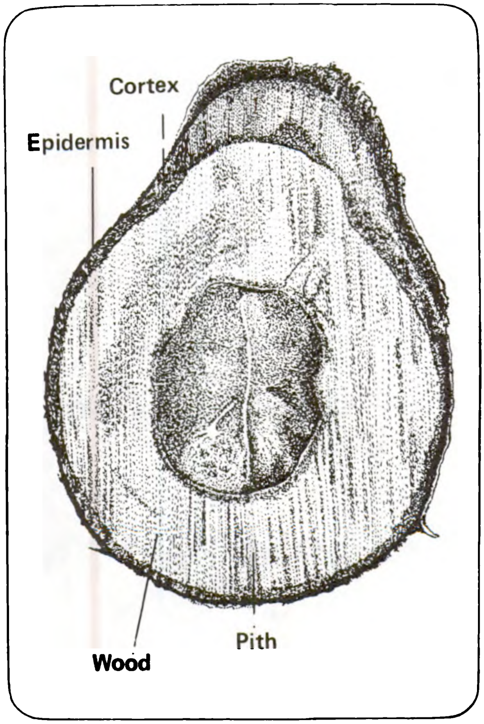


Figure 23. *Internal structure of the stem.*

ligneous layer or the wood. In the center of the stem is a prominent pith composed of parenchymatous cells. As the diameter of the stem increases, large quantities of xylem accumulate, giving the mature stem a woody consistency (Figure 23).

2.6 Root system

The principal characteristic of the roots of the cassava plant is their capacity for storing starches. This is why these organs have always had such great economic value.

The cassava root system has a low density of roots but deep penetration, giving the plant the capacity to resist long periods of drought. It has been found that the fibrous roots of cassava can penetrate about 2.5 m (Figure 24).

Plants grown from sexual seed develop a tap root and several secondary roots (Figure 25). It appears that the tap root always becomes tuberous and is the first root to do so.

In plants grown from vegetative material, the roots are adventitious; they form on the scarred lower base of the cutting which becomes callus tissue, and also arise from buds of the cutting that are underground. As they develop, these roots from a fibrous system.

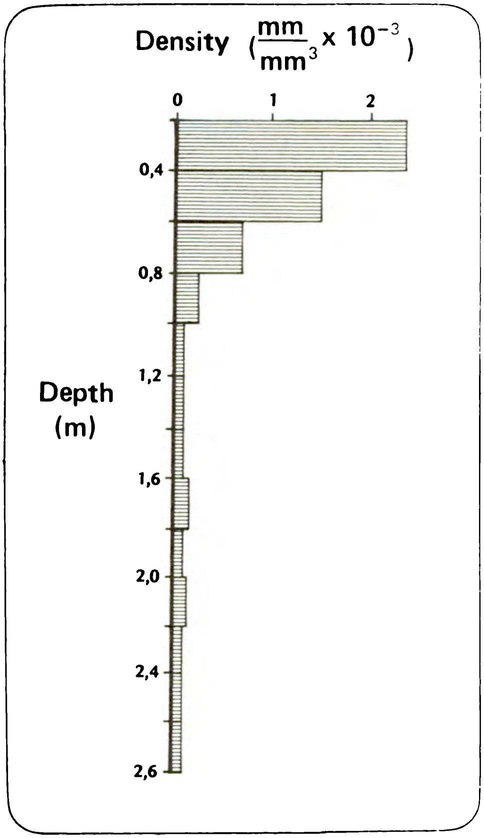


Figure 24. *Depth and density of the root system of cassava (Cv M MEX-59) seven months after planting (CIAT, 1980).*

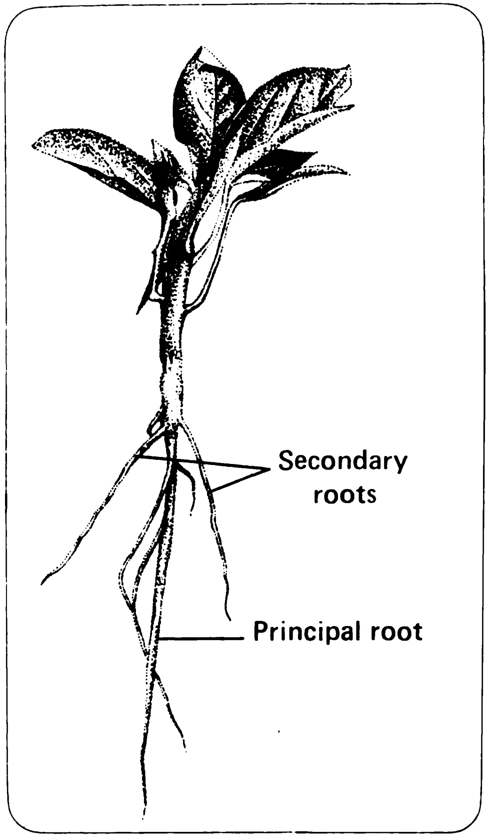


Figure 25. *Initial development of the root system of a cassava plant originating from sexual seed.*

Later, some of them begin to swell and become tuberous roots (Figure 26).

The plant absorbs water and nutrients through the fibrous roots. Apparently all of the roots have that ability, but it diminishes considerable when roots become tuberous. Only a few fibrous roots, generally fewer than ten, become tuberous on each plant; most remain fibrous and continue functioning as nutrient-absorbing roots. The number of tuberous roots is generally determined in the crop's early growth stages.

Tuberous roots of cassava are morphologically and anatomically identical to the fibrous roots. The essential difference is that the root's direction of growth changes from longitudinal to radical when starch accumulation begins. However, this does not

Figure 26. *Initial development of the root system of a cassava plant originating from vegetative material.*

imply that the root does not continue growing lengthwise.

As mentioned previously, the tuberous roots of cassava result from the secondary growth of the fibrous roots. This means that the soil is penetrated by thin roots, and that enlargement of roots begins only after that penetration has occurred.

2.6.1 Characteristics of the root system

2.6.1.1 External and internal components

Externally, the distinguishable parts of the root system of an adult cassava plant are: the fibrous roots, tuberous roots that end in a fibrous root, and the peduncle, which originates in the neck of tuberous roots and connects them to the stem (Figure 27).

The size of the peduncle varies greatly, from very short and considered as sessile ($<$ than 1 cm in length), to long ($>$ than 8 cm in lenght). The tuberous root of cassava is comprised of three essential parts: the skin, the starchy flesh and the central fibers (Figure 28).

The skin:

The skin is formed by the periderm and the cortex. The periderms is made up of dead cork cells that surround the root surface. As the root increases in diameter, the continuity of the cellular layers is broken, causing longitudinal fissures that characterize the surface of the cassava root. However, other cork cells from beneath these crack and reestablish the tissue.

The basic colors of the periderm are white or creme and light or dark brown; dark brown is most common. The surface can be wrinkled or smooth. These characters are among the most stable ones of the varieties.

Underneath the periderm is the cortex or cortical layer, which is 1 to 2 mm thick; its color can be white, creme or pink. Compressed in this layer are the sclerenchyma, the cortical parenchyma, and the phloem tissues containing a cyanogenic glucoside, which is responsible for the formation of hydrocyanic acid. This layer also contains

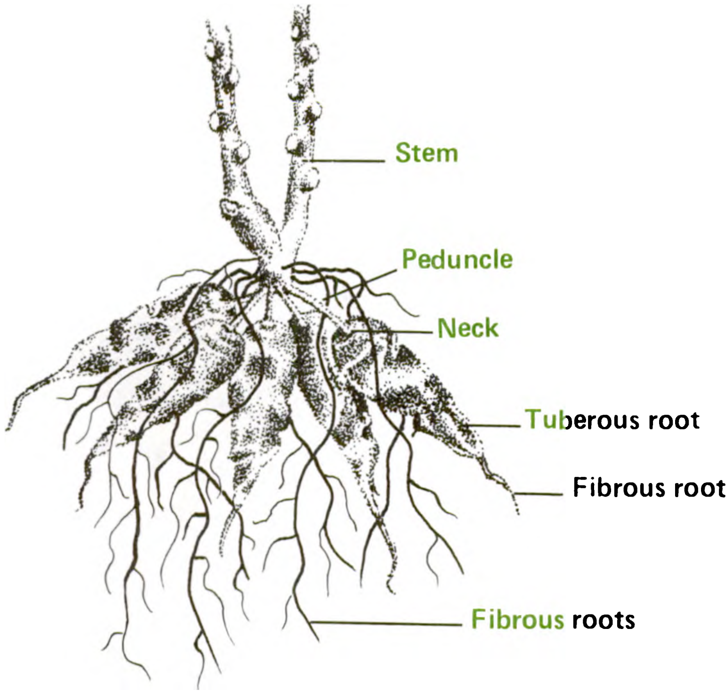


Figure 27. *Components of the cassava root system.*

the laticiferous canals, present especially in the young roots.

The flesh:

This is a solid mass composed principally of secondary tissue of the xylem derived from the cambium that surrounds the flesh. The cells contain an abundance of starch in the shape of round granules.

The central fibers:

In the center of the root are rows of hard vessels of xylem parenchyma, which form the root's central fibers. The toughness, length and width of these fibers are varietal characteristics influenced by climatic conditions and the plant's development process.

2.6.1.2 Shape and size of tuberous roots

The shape and size of the tuberous roots vary greatly. The conditions under which the plant develops have a marked influence on this character.

At CIAT, three basic shapes are considered: cylindrical, fusiform, and conical. Other institutions include other intermediate shapes, such as cylindrical-conical (Figure 29).

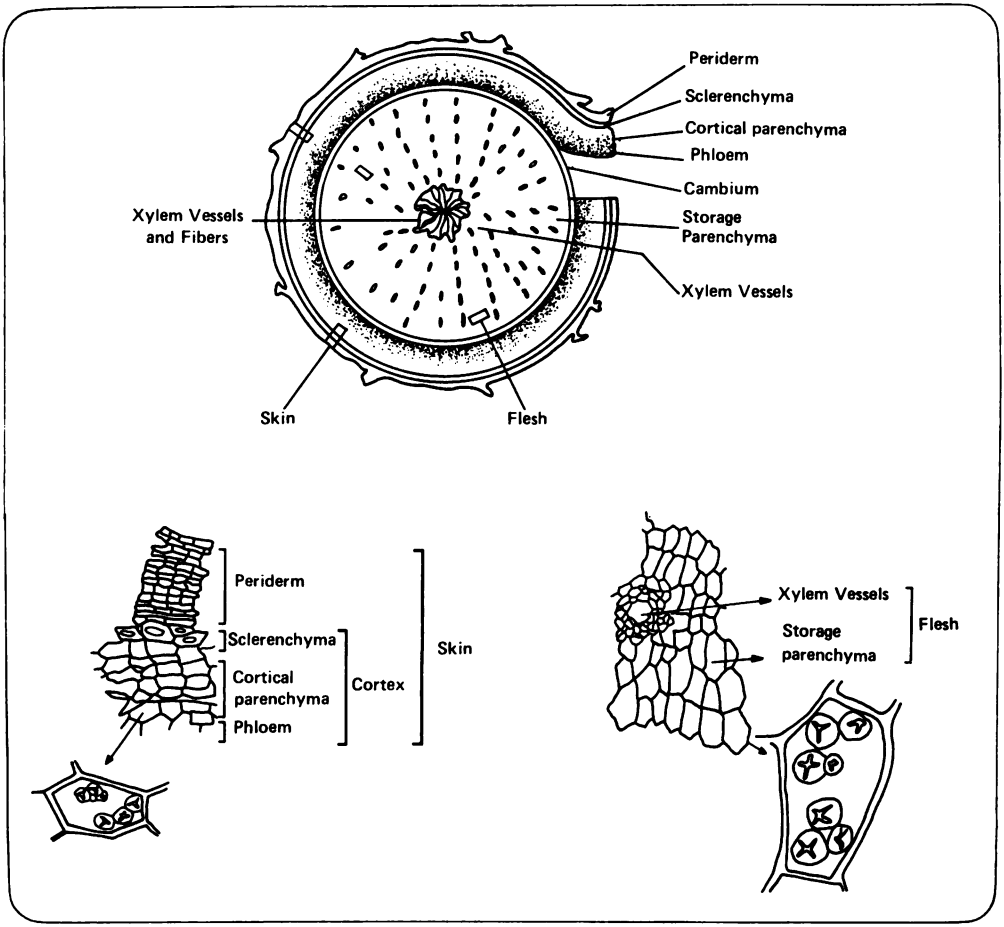


Figure 28. *Tissues comprising a tuberous cassava root.*

2.6.1.3 Distribution of roots

In addition to being a varietal factor, root distribution is influenced by the position in which the cutting is planted and by the angle of the cut of the stake. Cuttings planted vertically produce roots around the callus that forms on the lower tip of the stake; some roots growing from lateral buds of the cutting can also become tuberous roots. When the planting position is inclined, the tuberous roots also tend to form on the callus, but as in vertical planting, other roots can emerge from the lateral buds that are underground.

If the cutting is planted horizontally, tuberous roots are distributed along the cutting because of lateral buds, and on both ends of the stake (Figure 30).

If the cut is straight, roots will be produced around this cut; if the cut is slanted, the roots will be concentrated on the lower end of the cut (Figure 31).

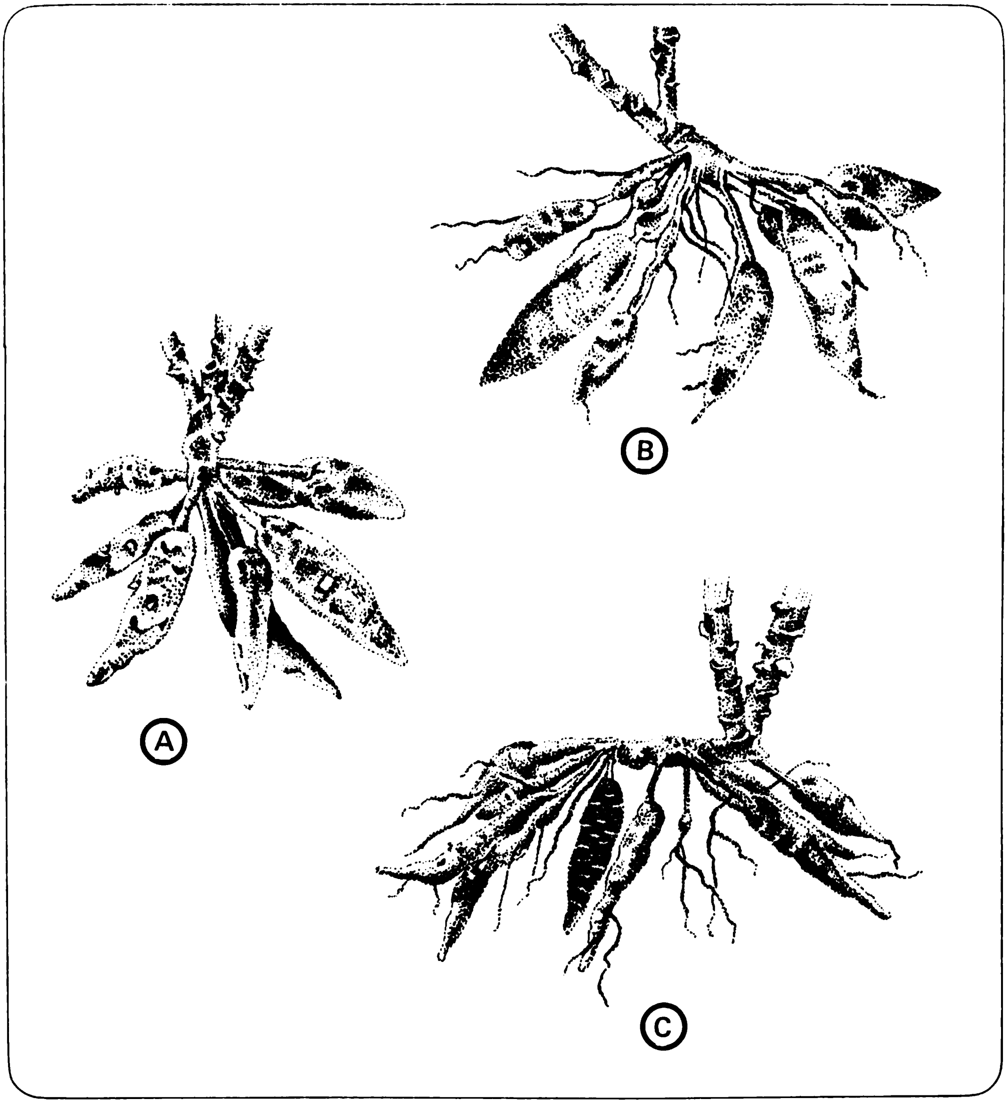


Figure 29. *Shapes of tuberous cassava roots (taken from: Catalogo de la colección de yuca Manihot esculenta (Crantz) del CATIE, 1980).*

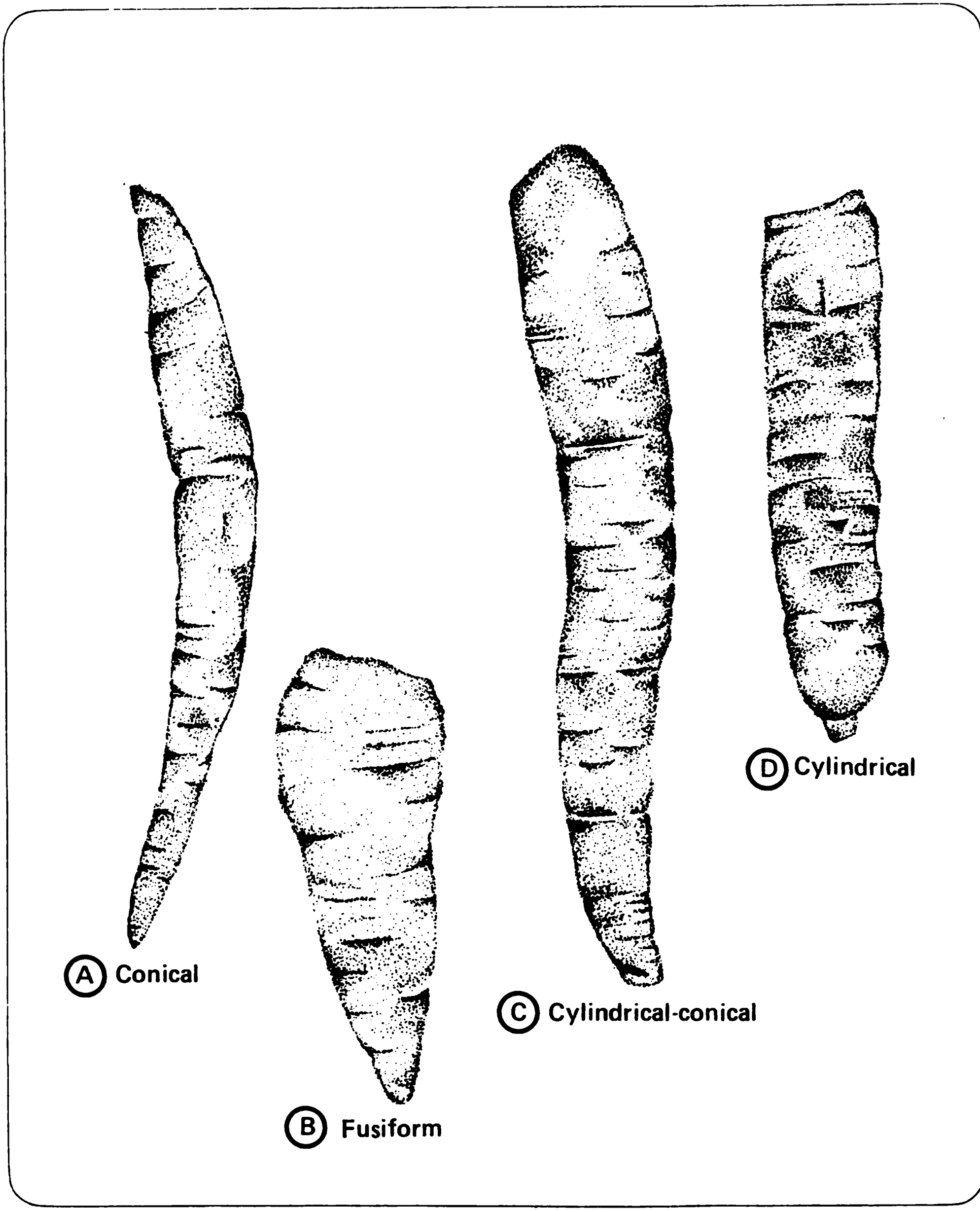


Figure 30. *Distribution of the cassava roots depending upon the planting position of the cutting (A) vertical, (B) inclined, and (C) horizontal.*

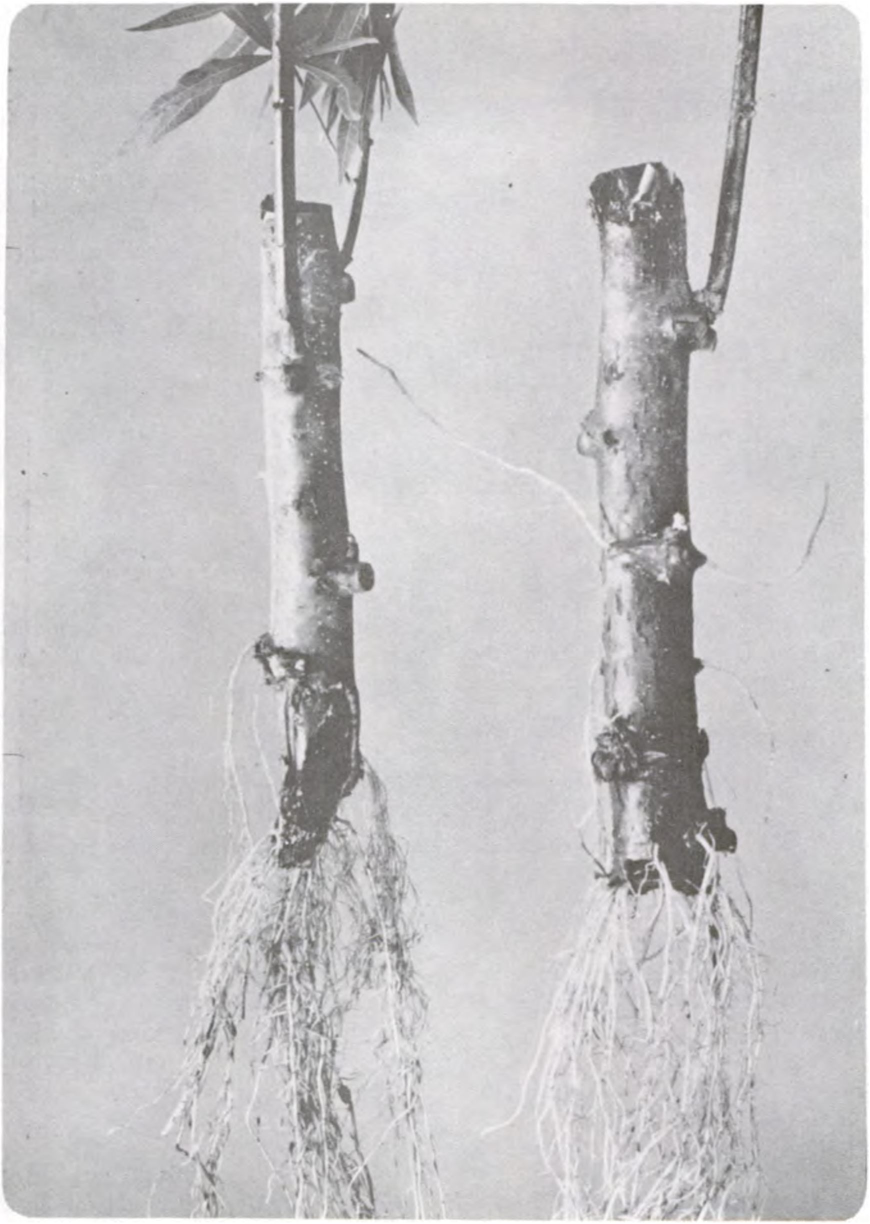


Figure 31. *Distribution of the roots according to the cutting angle on the stake.*

3. Hydrocyanic Acid Content

Cassava contains a cyanogenic glucoside called linamarin, which hydrolyzes in the presence of enzymes (linamarase) and acids, forming hydrocyanic acid in amounts that range from harmless to fatal. The reaction produced is the is the following:

$$\underset{\text{Linamarin}}{C_{10}H_{17}O_6N} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Acetone}}{(CH_3)_2} + \underset{\text{Hydrocyanic Acid}}{HCN}$$

The hydrocyanic acid is concentrated mainly in the cortex of the root; it is also found in smaller quantities in the leaves and other plant organs.

Environmental conditions can affect the hydrocyanic acid content, making a sweet cultivar from a given growing zone become bitter in another region.

Although cassava varieties earlier were classified botanically as sweet and bitter according to the hydrocyanic acid content in the roots, this is not done now because the acid content is not stable. In general terms, varieties having a hydrocyanic acid content greater than 50 ppm in the root are considered bitter and cannot be used in fresh form for human food or animal feed.

Although there are some aspects of cassava plant morphology still to be investigated, the information given in this audiotutorial unit should complement and clarify the knowledge that professionals working in cassava already have.

Evaluation

I. ***Complete the blanks.***

1. ***Cassava has been considered as a species originating in____________________________ and its most probable center of origin is______________.***

2. ***The taxonomic classification of cassava is:***

   Class:
   Subclass:
   Order:
   Family:
   Tribe:
   Genus:
   Species:

3. ***Three synonyms of the current scientific name of cassava are:***

   a.____________________
   b.____________________
   c.____________________

4. ***The number of chromosomes of the species is 2N = ____________________________***

5. *Plant characteristics are grouped as ________________ and characteristics.*

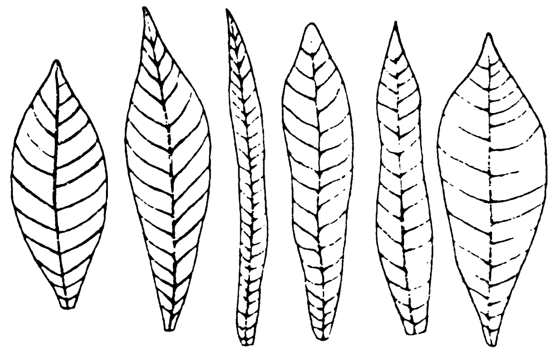
The first type typifies ______________________ or ______________ ; the second type is the result of tha _______________ on the ______________ .

6. *In cassava, the arrangement of the leaves on the stem, or phyllotaxy, is ________________ .*

II. Identify the parts indicated in the following drawings.

7. *Different lobe shapes:*

a. ____________________
b. ____________________
c. ____________________



(a) (b) (c) (d) (e) (f)

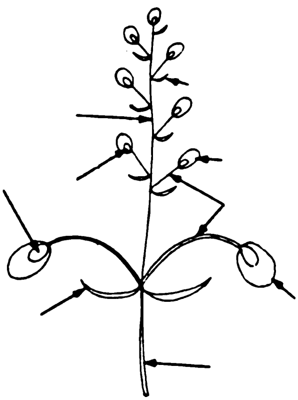
d. ____________________
e. ____________________
f. ____________________

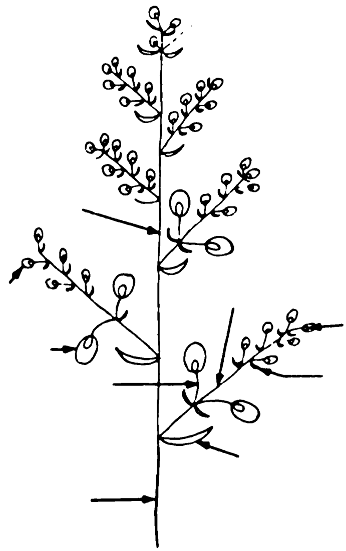
8. *Structural arrangements of cassava inflorescences:*

(a) (b) (c) (d)

a. ____________________ *c.* ____________________
b. ____________________ *d.* ____________________

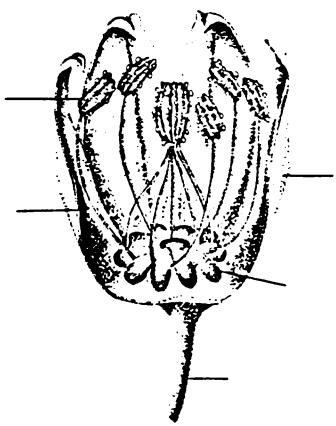
9. *Identify these two structures and give the respective botanical names for the parts indicated:*

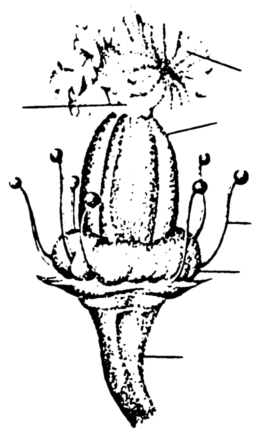




a. ____________________ b. ____________________

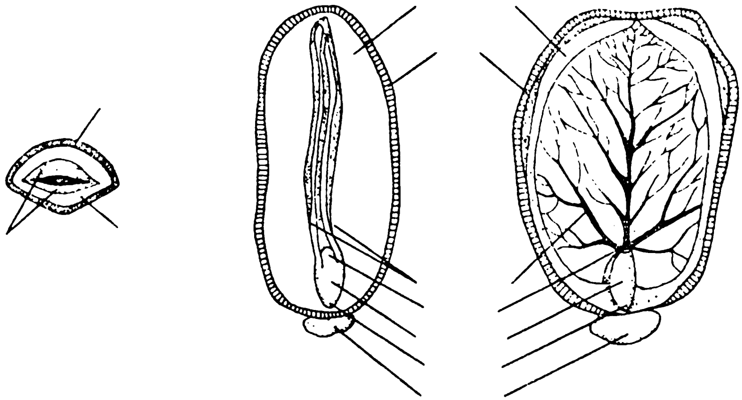
10. *Male and female flowers:*



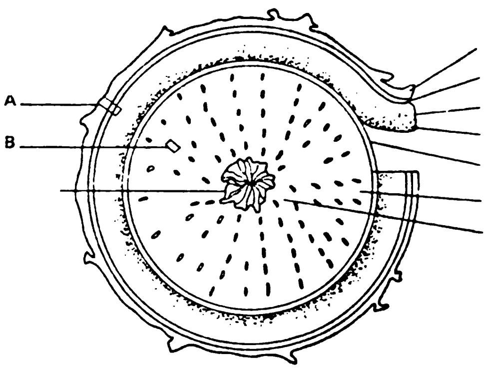


a. ____________________ b. ____________________

11. Seed (internal constituents).



12. Internal structure of a tuberous root.



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Glossary

Axil:	The space defined by the angle formed by the union of the leaf petiole or the cotyledon with the stem.
Basal disk:	Extremity of the pedicel that serves as the insertion point of all flower organs.
Bract:	Foliaceous appendage on the inflorescences.
Bract, pedicellular or secondary:	Triangular bract found on the base of the pedicel.
Bract, primary:	A bract appearing on the raceme and which is inserted directly into the axis of the raceme, at the base of the groups of flowers.
Bracteole:	Foliaceous organ inserted in the basal disk of the flower on the exterior of the calyx or perianth.
Branching, sympodial:	Type of branching consisting of a series of concrescent shoots, unit at their ends into one axial unit.

Bud: Organ that includes a meristem; the bud occasionally is protected by scales or by the future leaves or bracts. Its development can be vegetative (branches) or floral (racemes or floral buds).

Bud, axillary: The normal bud that originates in the axil of a leaf.

Bud scale: Modified leaf that protects the bud.

Capsule: Simple, dry, dehiscent fruit with two or more carpels.

Caruncle: Porous, prominent growth seen on the seed of some Euphorbiceae, Polygonaceae, etc.

Cortex: Primary tissue of the stem or the root, surrounded externally by the epidermis on the stem and by the periderm on the tuberous root; in the lower part (the root) it is also surrounded by the phloem.

Cotyledon: Can be one or a pair, from which comes the distinction between mono-and dicotyledons. Defined as a reserve organ of the seed during embryogenesis. The lobe shape is semi-spherical or semi-elliptical. Can be prominent (exalbuminous seed) or reduced, as in the case of cassava (albuminous seed).

Cyathium: Type of inflorescence found in the Euphorbiaceae family. Consists of one central female flower surrounded by five small groups of male flowers.

Decumbent: Said of that which is inclined, and principally of stems that are not erect, as in those tending to grow in a direction parallel to the soil.

Dehiscence: Phenomenon through which any organ opens spontaneously.

Dehiscenče, bicidal: Breaking open of a fruit into two parts or two series of parts; or the combination of two types of dehiscence.

Dehiscence, loculicidal: Dehiscence in which cracks or breaks originate along the midveins of the carpels.

Dehiscence, septicidal: Dehiscence in which the thin walls or dissepiments of a polycarpic and plurilocular fruit are decomposed. The number of parts fruit breaks into equals the number of carpels it has. This type of dehiscence is generally combined with some other manner of opening of the fruit.

Dissepiment:	In carpology, the small laminas or surfaces that divide the cavity of the fruit into two or more compartments. Generally applied to the carpellary walls of syncarpous gynoecia and of closed carpels.
Embryo:	In the spermatophytes, the embryo constitutes a primordium of the plant, whose fundamental parts, such as the root, the stem and the leaves, already appear to be outlined. The necessary reserves of nutrients for the plant are contained in the cotyledons of the embryo or in adjacent nutritive tissues.
Endocarp:	Internal layer of the pericarp which corresponds to the internal epidermis of the wall of the fruit.
Endosperm:	Reserve tissue of albuminous seeds. This tissue can be digested totally by the embryo (and thus it is lacking in mature seeds) or only partially. In the latter case, the same embryo utilizes the reserves to germinate the seed. The term endosperm has been used as a synonym for albumen.
Epicarp:	The external layer of the pericarp, corresponding to the external or inferior epidermis of the carpellary leaf.
Epidermis:	The superficial layer of cells covering all parts of the primary structure of the plant: the stem, leaves, roots, flowers, fruits and seeds.
Flower, unisexual (imperfect flower)	A flower lacking either the stamens or pistils.
Galactocyte:	Each of the laticiferous cells found in the embryo and from which originate the apocrine laticiferous tubes.
Hydrocyanic acid:	A very toxic compound whose chemical formula is HCN. As a cellular poison it inhibits cytochrome functions. In many plants it is found in a free state, and in others, in the form of glucosides.

Hypocotyl:	Part of the main stem of a plant between the insertion of the cotyledons (first or cotyledonary node) and the initiation point of the principal root at the insertion of the secondary roots.
Inflorescence:	The term inflorescence is given to the entire system of branching that becomes flowers. Inflorescence implies a branching and as such, is generally constant for each plant species; hence, the inflorescence is important in plant morphology and systematics.
Internode:	The section of the stem between two successive nodes.
Latex:	A generally milky juice that flows from injuries of many plants, such as the euphorbiaceas, the asclepiadaceas, etc. Latex is contained within the laticiferous tubes.
Leaf, simple:	Leaf having only one foliole and petiole.
Lobule:	A shallow lobe generally more or less surrounded by both laminar and solid organs. Strictly, it at most does not reach more than half the distance between the leaf edge and the midvein or between the edge and the base of the lamina, in the case of a plamate leaf or a petal.
Locule:	Cavity of the ovary containing an ovule.
Meristem:	Group of undifferentiated young cells that always have the possibility of dividing and initiating growth to form new organs.
Mesocarp:	The middle part of the pericarp between the epicarp and the endocarp.
Monoecious:	Having reproductive organs on separate structures but within the same individual.
Node:	Insertion point of the leaf in the stem, with one or more axillary buds in the axil of the leaf.
Ovary:	Enlarged basal portion of the pistil, which becomes the fruit.
Ovary, superior:	The ovary is free or superior when it has not attachment to the thalamus.

Panicle: Compound inflorescence of the racemose type in which the size of the sprigs decreases from the base to the apex, giving it a pyramidal aspect. It is a raceme of racemes.

Pedicel: Cylindrical part that unites the peduncle with the basal disk of the flower.

Peduncle: Cylindrical part constituting the axis of the inflorescence.

Perianth: Floral involucre not differentiated from the calyx and corolla; the petals and sepals are joined together.

Pericarp: Wall of the fruit resulting from the development of the ovarian wall. The pericarp is usually formed by three layers: epicarp, mesocarp, and endocarp.

Periderm (peridermis): Group of secondary tissues that take the place of the epidermis in plant organs causing growth in thickness. These tissues originate through the action of the so-called phellogen or suberogenous cambium, which produces suber toward the exterior and phellopderm inwards.

Petiole: Cylindrical part that unites the stem (or branch) with the lamina in a simple leaf, or with the foliole (s) in a compound leaf. If there is no petiole, the leaf is said to be sessile.

Phyllotaxy: Spirla positioning ot the leaves on the stem. It is defined by the projection of the angles of the leaves and the number of revolutions between two corresponding leaves.

Pith: Parenchymatous tissue occupying the central part of the stem.

Plumule: Part of the seed made up of the terminal bud and the leaf primordial; it is a continuation of the epicotyl.

Protogynia: Term given to the dichogamous plant, flower, etc., in which the gynoecium reaches sexual maturity before pollen is formed in the stamens for pollination.

Raceme: Type of inflorescence consisting of a simple alternate succession of floral buds.

Rachis, floral:	Axis of the inflorescence after the first floral insertion, directly following the peduncle.
Radicle:	Portion of the plant embryo that later gives rise to the primary root.
Raphe:	Suture in the seeds originating in the juncture of the funiculus with the external teguments of the ovule.
Root, adventicious:	Root that does arise from the radicle of the embryo nor from the principal root into which the radicle is transformed.
Root, fibrous:	An extended, thin root similar to a fiber.
Root, fusiform:	Spindle-shaped root having a large principal axis with small branchings called rootlets.
Root, secondary:	Root arising directly from the primary or principal root.
Root, tap:	Root with a preponderant or dominant axis, racemose type branching and secondary axes that have comparatively little development.
Root, tuberous:	A thickened root like a tuber.
Septate:	Divided into cells or compartments by transversal walls.
Staminoidium:	A stamen that has lost its function, remaining completely sterile until the end of its development.
Stigma:	Receptive part of the style to which the pollen adheres.
Stipule:	Foliaceous appendage located at the insertion of the leaf petiole on the stem or branch; there are generally two stipules.
Style:	Thin column of tissue that originates in the upper part of the ovary and through which the pollen tube grows.
Tepal:	Anthophore of the perigonium or perianth.
Testa:	Exterior covering of the seed. The external tegument of the seed corresponds to the secundine of the ovule.
Wood:	End product of secondary tissues produced by the cambium inward.

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