International Institute of Tropical Agriculture (IITA)

Morphology and growth of plantain and banana

Rony Swennen, Rodomiro Ortiz

Research Guide 66

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Rony Swennen, Rodomiro Ortiz

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Rony Swennen, formerly at IITA, is Professor at Katholieke Universiteit Leuven, Belgium. Rodomiro Ortiz, formerly at IITA, is Professor at The Royal Veterinary and Agricultural University, Denmark.

International Institute of Tropical Agriculture (IITA)
Training Program
PMB 5320
Ibadan
Nigeria

Fax: (234 2) 241 2221
Telephone: (234 2) 241 2626
Telex: 31417 or 31159 TROPIB NG
E-mail (Internet): IITA@CGNET.COM

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	Ayotunde Oyetunde
Text processing	Kehinde Jaiyeoba
Artwork	Chiweta Onianwa
	Charles Geteloma
Layout	Nancy Ibikunle
Coordination	Rainer Zachmann

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Morphology and growth of plantain and banana

Objectives. This guide is intended to enable you to

- classify plantain and banana
- analyze the growth cycle
- describe morphological features and functions of corm, suckers, roots, pseudostem, leaves, and inflorescence

Study materials

- Inflorescences and fruits of different *Musa* groups
- Plant parts of plantains and bananas

Practicals

- Differentiate *Musa* groups based on the criteria listed in Section 1
- Analyze, measure, and describe morphological characteristics

Questions

1 How did plantain and banana cultivars evolve?
2 What is the ploidy level of all plantains and almost all important bananas?
3 Where are plantain and banana important as food crops?
4 How can you distinguish plantain and banana by their method of consumption?
5 What are the parts of a complete *Musa* inflorescence?
6 How do you measure the height of a pseudostem?
7 How are genotypes classified by genome composition?
8 What are the consequences of 'high mat'?
9 How does the yield differ among growth cycles?
10 How can you differentiate the vegetative from the reproductive phase?
11 What are mini-setts?
12 Under what circumstances does a new corm develop above the planted corm?
13 What are the four types of suckers?
14 What types of suckers are the best planting material?
15 Where do most roots develop?
16 What is the importance of feeder roots compared to explorer roots?
17 How should you count the number of leaves?
18 How many hands emerge per day?
19 What does parthenocarpy mean?

Morphology and growth of plantain and banana

Abstract. Plantain and banana (*Musa* spp.) are giant perennial herbs which originated in Southeast Asia. *Musa* is an important food crop in the humid forest and mid-altitude ecologies of sub-Saharan Africa. Several criteria are used to distinguish the different types of cultivated plantain and banana, evolved from *M. acuminata* and *M. balbisiana*. The corm is the real stem of the *Musa* plant and produces 10–15 buds, which may develop into branches called suckers.

Suckers are used as planting material. Foliage leaves form the pseudostem, which supports the inflorescence. The inflorescence may be complete or incomplete, depending on whether it includes all or only parts of a *Musa* inflorescence: female flowers, neutral flowers, and male bud. Fruit development includes the maturation and ripening periods.

1 Plantain and banana

Plantain and banana (*Musa* spp., or *Musa* in this document) are giant perennial herbs (Figure 1) which originated in Southeast Asia. Plantain and banana cultivars evolved by natural hybridization between the two species *M. acuminata* (contributing genome A) and *M. balbisiana* (contributing genome B).

All plantains and almost all important bananas are triploid (2n = 3x = 33 chromosomes). Plantain and banana are monocotyledonous plants, belonging to the section Eumusa within the genus *Musa* of the family Musaceae in the order Scitamineae (Table 1).

Plantain and banana are important food crops in the humid forest and mid-altitude agroecologies of sub-Saharan Africa. They provide more than 25% of the carbohydrates for 70 million people. The area between the lowlands of Guinea and Liberia in West Africa and the central basin of Zaire in Central Africa produces more than 50% of the plantain in the world.

Table 1. Taxonomic classification of the most important plantain/banana cultivated in Africa.

Class	Monocotyledonae
Order	Scitamineae
Family	Musaceae
Genus	*Musa*
Section	Eumusa
Species	*M. acuminata* (AA)
	M. balbisiana (BB)
Groups	AAA dessert and highland beer and cooking bananas
	AAB plantains and dessert bananas
	ABB cooking bananas

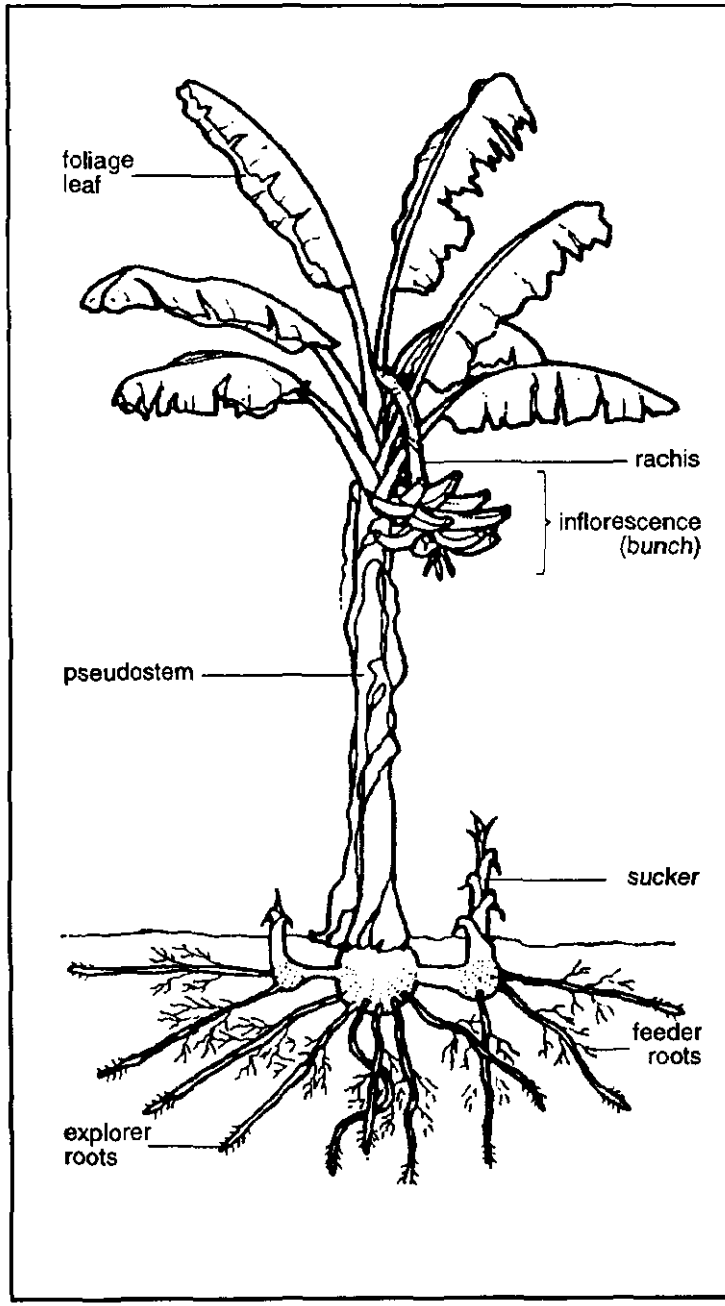


Figure 1. Morphology of plantain.

In the East African highlands, beer and cooking bananas are the staple food and the region records the highest consumption figures in the world. Plantain and banana are high-yielding crops and particularly suited to the farming systems in sub-Saharan agroecologies.

Several criteria are used to distinguish the different types of plantain and banana further:

- form of consumption
- inflorescence type
- height of pseudostem
- genome composition

Form of consumption. Plantain and cooking/beer banana are easily distinguished from dessert banana by their method of consumption. Plantain and cooking /beer banana require some form of processing, whereas dessert banana is eaten raw when ripe.

Inflorescence type. All banana cultivars have the same type of inflorescence (or 'bunch'). Plantains have different types, and this can be used to subdivide and classify plantains.

Bananas have the complete *Musa* inflorescence: female flowers, neutral flowers (which do not develop into fruits, and fall off during bunch maturation), and a terminal male bud (see Section 7).

Plantain is subdivided into:

- French plantain (also called 'Hembra')
- French Horn plantain
- False Horn plantain (also called 'Macho', 'Harton')
- Horn plantain

The subdivision depends upon:

- completeness of inflorescence at maturity
- presence of neutral flowers and male bud at maturity
- number of hands
- number and weight of fingers

See Table 2 for details.

Table 2. Classification of *Musa* according to inflorescence type.

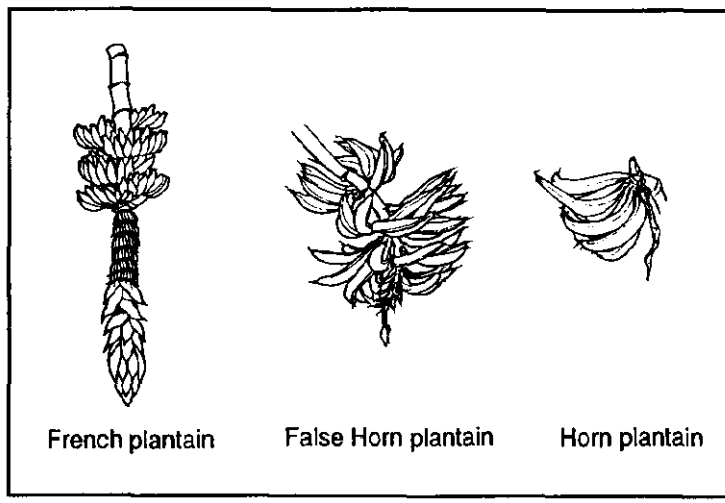
Group	Inflorescence	Neutral flowers	Male bud	Hands (no.)	Fingers (no.)	Fingers (g)
Banana	Complete	Many	Yes	5–10	65–155	100–300
French plantain	Complete	Many	Yes	6–12	60–170	10–300
French Horn plantain	Incomplete	Many	No	7–8	30–85	200–300
False Horn plantain	Incomplete	Few	No	5–12	25–80	230–400
Horn plantain	Incomplete	None	No	1–5	1–50	250–610

Figure 2 illustrates the three main inflorescence types: French, False Horn, and Horn plantains. French Horn plantain is an intermediate type between French plantain and False Horn plantain.

French plantain. The inflorescence is complete at maturity. Hands consist of numerous rather small fingers, followed by the bunch axis covered with persistent neutral flowers. The terminal male bud is large and persistent.

False Horn plantain. The inflorescence is incomplete. Hands consist of large fingers followed by a few neutral flowers. At maturity, no male bud is present.

Figure 2. Inflorescence types.

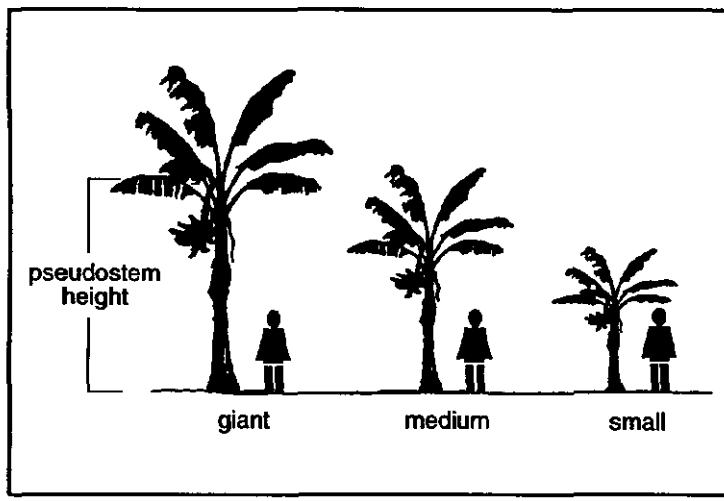


French Horn plantain. The inflorescence resembles the inflorescence of False Horn plantain, but French Horn has many more neutral flowers.

Horn plantain. The inflorescence is incomplete. There are few hands, consisting of a few large fingers. Neutral flowers and male bud are not present. A tail or protuberance terminates the bunch axis. Horn plantain resembles False Horn plantain, but has larger fingers and no neutral flowers.

Height of pseudostem. The height of the pseudostem, that is, the distance between the soil and the petioles of the highest leaves, is used for subgrouping plantain cultivars into 'giant', 'medium', and 'small' (Figure 3). *Musa* clones with short internodes are called 'dwarf' cultivars.

Figure 3. Classification of *Musa* by height of pseudostem.



Genome composition. Genotypes are classified by the genome composition, that is, the expression of *M. acuminata* and *M. balbisiana* characteristics (Table 3). Dessert banana and East African highland cooking/beer bananas are categorized as AAA, plantains as AAB, and cooking bananas as ABB.

Table 3. Classification of *Musa* according to genome composition, form of consumption, and growing area.

Genome	Form of consumption	Growing area
AAA	Dessert banana	Throughout Africa
AAA	Cooking/beer bananas	East African highlands
AAB	Plantains/dessert bananas	Humid lowlands of West and Central Africa
ABB	Cooking bananas	East African highlands

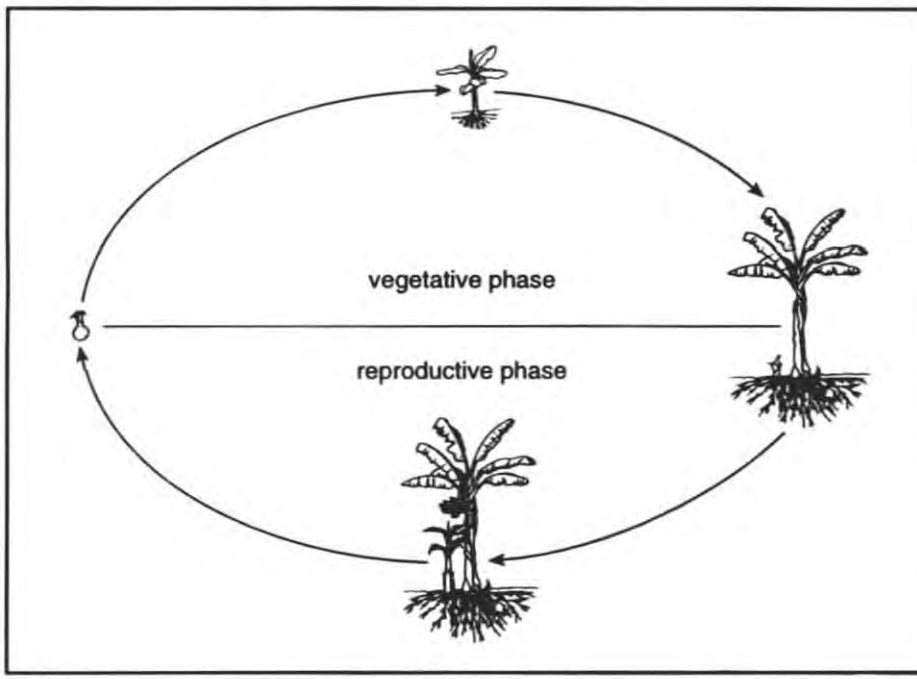
2 Growth cycle

Plantain and banana are perennials which produce succeeding generations of ratoon crops. The first cycle after planting is called the plant crop. The ratoon is the sucker succeeding the harvested plant. The second cycle is called the first ratoon crop. The third cycle is the second ratoon crop, and so on.

The growth cycle of *Musa* consists of two phases (Figure 4):

- vegetative phase
- reproductive phase

Figure 4. Growth cycle of *Musa*.



Vegetative phase. The vegetative phase (or 'shooting') begins with the production of leaves by the planted sucker, and ends when the inflorescence appears at the top of the plant.

Reproductive phase. The reproductive phase begins with the transition of the vegetative meristem into a floral shoot. The division of phases is arbitrary, and it takes several weeks before the inflorescence emerges at the top of the plant. The fruit filling period, that is, the time between flowering and harvest, completes the reproductive phase and the growth cycle.

During the growth cycle, plants develop essentially three major components:

- an underground corm, producing suckers and roots
- a pseudostem, consisting of encircling leaf sheaths, and carrying the leaves
- an inflorescence, containing female flowers that develop into fruits

The length of the growth cycle depends on the cultivar. Giant cultivars have more foliage leaves and flower later than medium-sized plants. Small cultivars flower earlier and have less foliage.

Differences in yield **per growth cycle** can be large. Under the best growing conditions, the yield of the second cycle is higher than the yield of the first cycle. Yield per growth cycle of cultivars with a long growth cycle may be higher than that of cultivars with a short growth cycle. However, yield adjusted **per unit of time** (t/ha/year) may be similar for cultivars of short and long growth cycles.

The mother plant and the ratoon are in competition for resources. During the vegetative phase most of the resources are directed to the growing mother plant. During flowering, ratoon development increases.

After flowering, resources are directed back to the mother plant for fruit development. After harvest, resources are directed to the ratoon again.

After several ratoon crops, *Musa* corms grow above soil level. Roots and shoots grow to the soil surface until they eventually grow out of the ground. This phenomenon is called 'high mat'.

High mat is the result of the upward movement of the meristem of corms and suckers. Consequently, roots easily dry out. Additionally, the plant is no longer firmly anchored in the soil and becomes susceptible to lodging. High mat is particularly dangerous in windy areas. Plantains are especially prone to high mat.

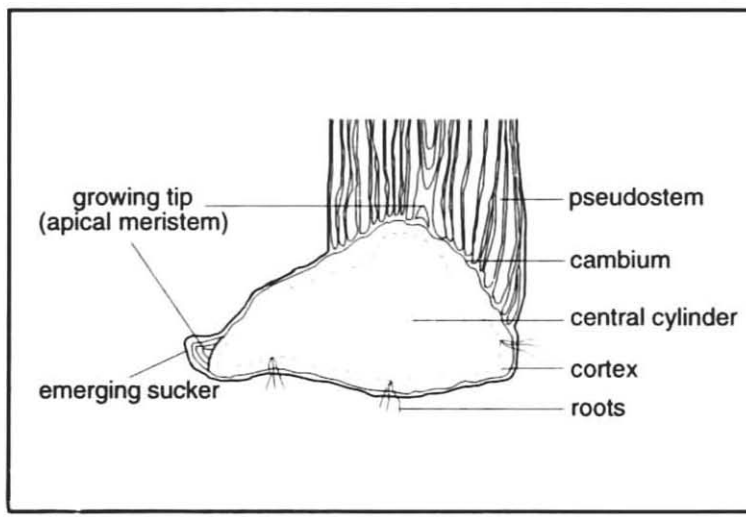
3 Corm

The corm is the real stem of the *Musa* plant (Figure 5). It grows underground and is sometimes inaccurately called a bulb or rhizome.

The corm is covered with closely packed leaf scars, which form rings around the corm. The internodes are extremely short. Each leaf scar carries a bud. Ten to fifteen buds on each corm develop into suckers. Pieces of corm carrying such buds, called mini-setts, can be used as planting material.

The corm is differentiated into two regions, the central cylinder and the cortex. A high concentration of longitudinal vascular bundles marks the junction between the two regions. Vascular bundles are also found all over the corm, but in lower concentration.

Figure 5. Section through a corm.



The corm has the shape of an inverted cone. The top of the cone is dome shaped, with the growing tip (apical meristem) at the crest of the dome. Throughout the growth period, the growing tip remains near soil level. The cambium is just below and separates the corm from the growing tip, the leaves, and the inflorescence.

Four months after planting, the corm shows any one of three development types:

- A new corm develops at some distance above the planted corm. Both corms are connected.
- A new corm grows, absorbing the originally planted corm.
- The size of the planted corm increases slightly. Simultaneously, a second corm of the same size develops on the planted corm.

The first development type is caused by planting too deep. The second and third types are common in vigorously growing *Musa* cultivars.

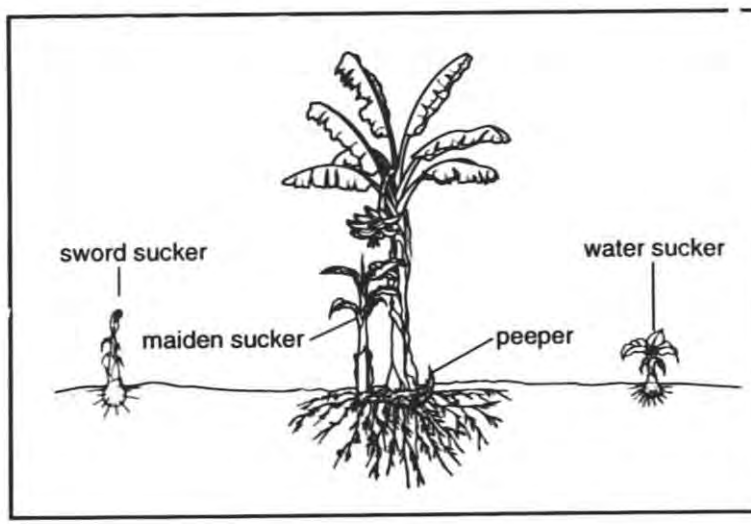
4 Suckers

A corm produces 10–15 branches called suckers or daughters. Suckers are lateral shoots from the main plant. Suckers can be used for planting. The whole unit of corm and suckers is called the mat or stool.

There are four types of suckers (Figure 6):

- peepers are small suckers, appearing just above the ground
- sword suckers are large suckers with lanceolate leaves
- maiden suckers are large suckers with foliage leaves and large corms
- water suckers are suckers with small broad leaves and small corms

Figure 6. Suckers.



Sword and maiden suckers are the best planting material.

In plantation systems, farmers cut down the mother plant after harvest, and reduce the number of suckers ('thinning') to maximize yield. Thinning is necessary to avoid competition, and it should start at flowering to prevent production of small bunches. The most vigorous sucker should be selected to replace the mother plant. The selected sucker is called the ratoon.

In backyard systems, thinning is often not carried out, and many suckers grow simultaneously.

Plants established from suckers have adventitious root systems, which originate from stem (corm) tissue. After planting, growth begins with root formation. Roots grow to more than 40 cm before the first leaf appears. Under favorable conditions, 4.5 months after planting, total primary root length is over 6.5 m.

Roots are formed in groups of 3–4. Most roots grow horizontally in the upper 15 cm of the soil, and under mulched conditions in the upper 0–5 cm. Mulching increases root development (length and branching) around the corm. New roots continue to form until the plant flowers.

New roots may also appear above the soil. The new roots grow downwards and, depending on cultural practices, enter the topsoil or die off before reaching the soil.

A healthy root is white and fleshy when young, becoming corky when mature. A mature root has prominent lacunae (cavities) in the cortex, and large vessels and phloem strands in the center. Xylem elements form when root elongation has stopped.

A root system consists of primary, secondary and tertiary roots. Secondary roots are those that develop on primary roots, while tertiary roots develop on the secondary roots.

Roots (all three types) have active growing tips (zones of elongation) which push the root through the soil. Just behind the growing tip of the primary root is a zone of 7–8 cm with root hairs. Behind the root hair zone is a bare zone, and then a long zone with secondary roots.

Primary roots can be classified as:

- explorer roots
- feeder roots

Explorer roots are mainly for anchorage. Feeder roots, which usually grow from explorer roots, take up water and nutrients. Explorer roots are thicker than feeder roots.

6 Pseudostem, leaves

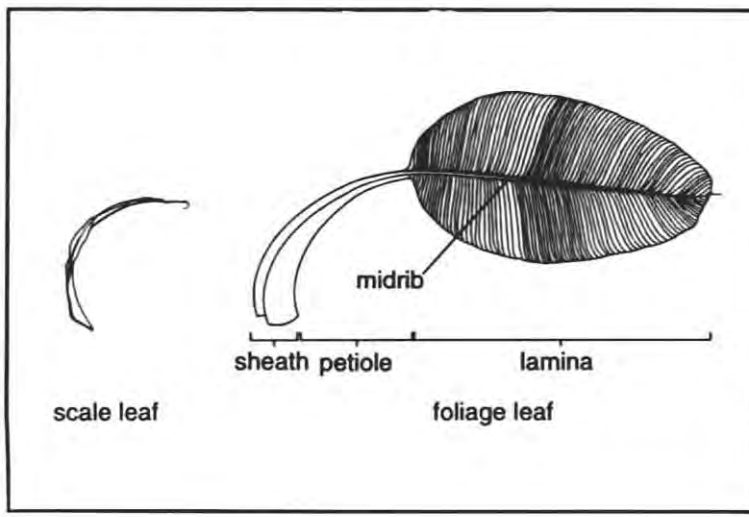
Plantain and banana are giant herbs, not trees. They do not produce wood. The cylindrical structure growing from the corm and carrying the foliage is a pseudostem, not a real stem, because the meristem remains near soil level. The pseudostem consists of overlapping leaf sheaths.

Leaves are formed by the apical meristem and emerge from the middle of the pseudostem.

There are two types of leaves (Figure 7):

- scale leaves
- foliage leaves

Figure 7. Scale leaf and foliage leaf.



Scale leaves. Scale leaves, also called scales, are rudimentary leaves, almost without lamina, and first formed underground on buds. Later, scale leaves form on peepers and sword suckers above ground.

Foliage leaves. Foliage leaves consist of sheath, petiole, midrib, and lamina.

Initially, sheaths entirely enclose (wrap around) each other. Later, new leaves growing in the center of the pseudostem force the sheaths apart. Sheaths have a thin papery margin at each side, and they are tightly packed together to form the pseudostem, which later supports the inflorescence. The top end of the sheaths gradually contracts into a channel-like petiole that extends into the midrib of the leaf.

The leaf lamina, or blade, has two halves, which are usually different from each other. Each half is a lateral extension of the midrib. Where the two lamina halves join the midrib, two pale lines called pulvinar bands are visible. Turgor changes in the pulvinar bands are responsible for the movement of the lamina halves. On dry days, the lamina halves bend downwards, reducing the leaf area exposed to the sun.

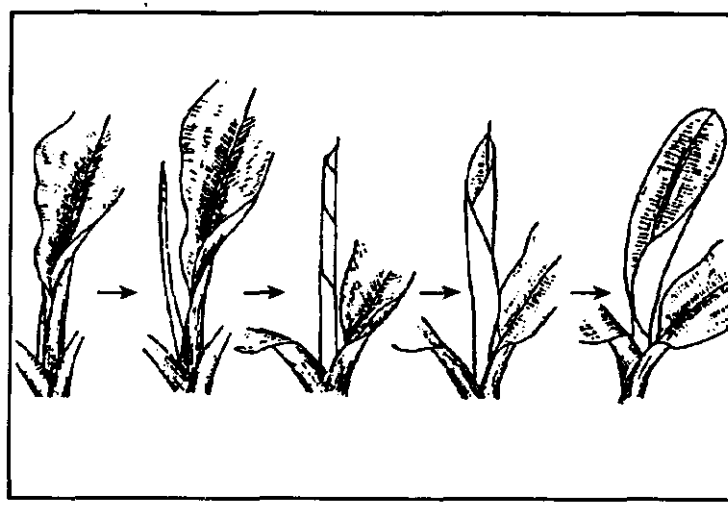
Lamina veins run parallel to each other in a long S-shape from midrib to margin. The central portion of the S is straight and covers nearly the entire lamina half. A few centimeters from the margin, veins curve towards the leaf tip and join into a marginal vein. Veins do not branch. This means that leaves can tear easily.

The tail-like extension at the leaf tip is called the precursory appendage. The extension is a few centimeters long. After leaf emergence, it withers quickly and falls off.

Leaves unroll in several (artbitrary) stages (Figure 8). First, the precursory appendage becomes visible. Then the 'cigar' (leaf lamina rolled around the midrib) appears. It stands up for some days. The left lamina half unfolds, followed by the right lamina half. The next precursory appendage becomes visible as soon as the leaf is unfurled.

Under favorable conditions, leaves emerge at 7–10 day intervals. In a healthy plant, a new leaf is emerging by the time the previous leaf fully opens.

Figure 8. The stages of unrolling of *Musa* leaves.



Leaf symmetry makes it possible to count the number of foliage leaves formed by a certain cultivar. The first foliage leaf is symmetric and counted as number 0. The next foliage leaf, which is asymmetric, is counted as number 1. The number of leaves varies according to cultivar, while leaf size depends on both cultivar and growth conditions. In plantain, plant height depends on the number of leaves produced before flowering:

- giant cultivars have more than 40 foliage leaves,
- medium cultivars have 32–40 foliage leaves,
- small cultivars have less than 32 foliage leaves.

A positive correlation exists between leaf length (L) and leaf area. Leaf area can be estimated as:

$$0.8 \times L \times W \text{ (W = leaf width)}$$

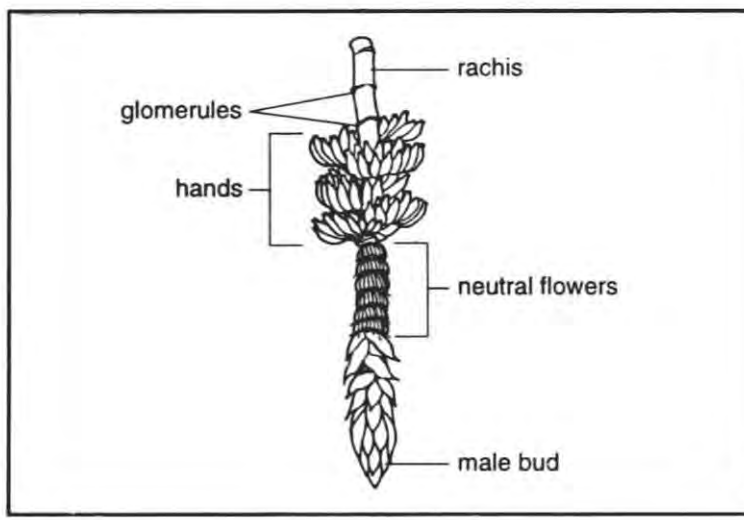
The leaf area of each new leaf is larger than its predecessor except for the last 7–11 leaves (by this stage, flowering would have started). New leaves do not emerge after flowering.

7 Inflorescence

Upon flower initiation, the apical meristem converts into an inflorescence (Figure 9), which emerges through the center of the pseudostem, at the top of the plant. The inflorescence is supported by a rachis or fruit stalk, which is attached to the pseudostem for its support. The pseudostem and rachis provide a vascular connection between roots, leaves, and inflorescence (bunch).

Banana and French plantain cultivars have pendant bunches. Other plantain cultivars have subhorizontal or horizontal bunches.

Figure 9. Inflorescence.



The following events characterize flowering:

- elongation of internodes on the corm
- suppression of leaf development
- development of bracts
- initiation and development of inflorescence

The protuberances on the rachis are called glomerules. Each glomerule bears a group or cluster of flowers, the 'hand'. In banana and French plantains, flowers are arranged in two rows, while in other plantains, flowers are arranged in one row. Hands are arranged in a spiral, beginning at the base of the inflorescence. A reddish bract, which is in fact a modified leaf, covers each hand. One to three hands emerge per day.

The inflorescence consists of:

- female flowers
- neutral flowers
- male bud

Female flowers. Usually, the first glomerule does not bear any flowers (or hand). The first hand is highly variable and often bears fewer female flowers than the second hand. The following 10 hands bear many female flowers. The number of female flowers in succeeding hands decreases gradually.

A female flower (Figure 10) consists of:

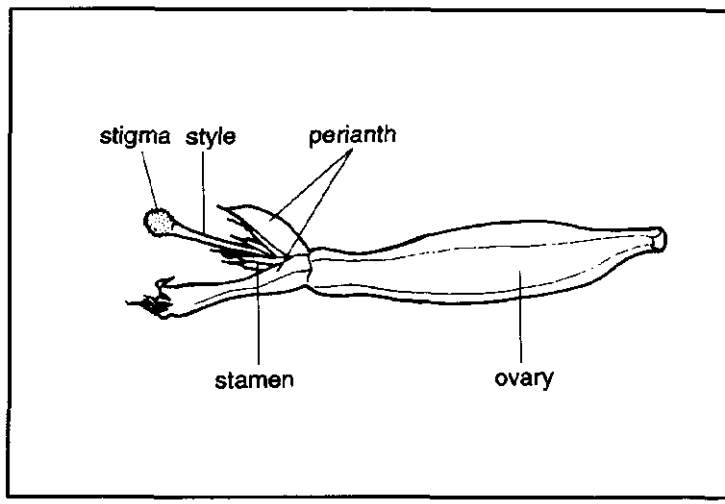
- a large ovary with about 300 ovules
- a style with a 6-lobed stigma
- stamens or staminodes
- a perianth

Thus, female flowers contain both female and male organs, but the female organs (ovary, style, and stigma) are more developed than the male organs (stamens).

Under favorable conditions, edible fruits (or 'fingers') develop from ovaries of female flowers, located on the first 10 flower-bearing glomerules. The fruits are parthenocarpic, that is, ovaries are unpollinated and grow into seedless fruit.

Neutral flowers. Neutral flowers (also called hermaphrodite flowers) follow female flowers on the rachis. Neutral flowers do not develop into fruits, and their stamens do not produce pollen.

Figure 10. Female flower.



Male bud. The reddish purple bud at the end of the bunch is called the male bud. The male bud consists of bracts covering two rows of male flowers. A male flower bears a short, slender ovary with a big nectary. No placental tissue develops. Style and stigma are slender. Stamens, although well developed, do not normally produce pollen.

Fruit development includes:

- maturation period
- ripening period

Maturation period. Fruit filling begins after the bract exposes the hand, and continues until harvest when fruits have reached full size. At the initial fruit filling stages, fresh and dry weights of the peel are higher than those of the pulp. In the later stages, this relation reverses. In the lowlands, the maturation period is about 3–4 months, while in the highlands, it can extend to 6 months.

Ripening period. The ripening period is the period from full fruit size until the peel becomes yellow. Ripening takes about 2 weeks.

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9 Suggestions for trainers

If you use this Research Guide in training

Generally

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.

- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listening to you.

- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.

- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.

- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, and so on). Allow consultation of handouts and books during examinations.

- Promote interaction of trainees. Allow questions, but do not deviate from the subject.

- Respect the time allotted.

Specifically

- Find out from trainees their experiences and knowledge on plantain and banana (10 minutes).

- Present and discuss the content of this Research Guide, using the study materials suggested on page 3 (1 ½ hours).

  Have plant parts available for each trainee. Illustrate growth characteristics of *Musa* groups with the help of slides.

  You may photocopy the tables and illustrations of the Research Guide on transparencies for projection with an overhead projector.

- In the field, and in groups of 3–4 trainees per group, carry out the practicals suggested on page 3 (2 hours). Compare and discuss the findings among groups.

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The International Institute of Tropical Agriculture (IITA) is an international agricultural research center in the Consultative Group on International Agricultural Research (CGIAR), which is an association of about 50 countries, international and regional organizations, and private foundations. IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in tropical sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.

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