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Morphology and growth of maize

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IITA Crop Production Guide 1

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December 1991

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IITA Crop Production Guides

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Kling, J.G. 1991. Morphology and growth of maize. IITA Crop Production Guide 1. Training Program, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 25 p.

Morphology and growth of maize

Objectives. This guide is intended to enable you to:

- describe the maize plant and its importance;
- describe morphological features and functions of the parts of a maize plant through the stages of seedling growth, vegetative growth, flowering and fertilization, and grain filling.

Study materials

- Plants at seedling stage, vegetative stage (2, 4, and 6 weeks after planting), flowering, and maturity.
- Ear shoots at various stages of development.
- Plant and ear samples of different maize varieties.
- Slides identifying different plant parts.
- Slides of various stages in the maize life cycle.

Practicals

- Dissect seedlings and plants and identify morphological features.
- Identify various stages of development of maize ears.
- Compare varieties and indicate distinguishing characteristics.

Questionnaire

1 To what plant family does maize belong?
2 Why is maize botanically unique among the cereal crops?
3 Where is the origin of maize?
4 What is the genetic origin of maize?
5 What is the average yield of maize worldwide?
6 What are three main components of the maize kernel? What are their functions?
7 What is the protein content of the endosperm of maize?
8 What are the two types of maize endosperm?
9 Describe the germination process in maize.
10 What is the difference between seminal and adventitious roots?
11 Where does the main root system of maize develop from?
12 Where is the growing point in maize located two weeks after planting?
13 Where is the leaf connected to the stem?
14 At what time are the last maize leaves initiated?
15 What depth can maize roots reach?
16 What does "monoecious" mean?
17 For how many days do maize tassels produce pollen?
18 How many pollen grains can a maize plant produce?
19 How many ear shoots does a typical maize plant initiate?
20 How many kernels can a typical maize ear produce?
21 When do maize silks emerge?

Morphology and growth of maize

Abstract. Maize is one of the most important food crops worldwide. It has a remarkable productive potential. However, considerable variation exists among varieties in morphology and growth habit. Management of a maize crop with respect to interaction of genotype and environment requires specific knowledge of maize growth and development.

1 The maize plant and its importance

Maize (*Zea mays* L.) and all major cereal crops are members of the grass family, *Gramineae*. Worldwide, wheat, maize, and rice are produced in greater quantities than any other crop. Of these crops, maize has the highest average yield per hectare (Table 1). Although it occupies less land area than either wheat or rice, it is second only to wheat in total production.

Maize has the basic structure of the grass family, having conspicuous nodes and internodes on the stem. The leaves grow in two opposite ranks; one leaf per node. Maize is botanically unique among the cereal crops. It is **monoecious** (having separate male and female inflorescences on the same plant) and it produces grains on lateral rather than terminal branches.

Table 1. World production of major cereal crops 1987 (FAO 1988).

Crop	Area harvested (million ha)	Yield (t/ha)	Production (million t)
Wheat	221	2.4	517
Maize	128	3.6	457
Rice	141	3.2	454

The origin of maize has been a matter of controversy for many years. The most common view is that it originated by domestication of the wild grass teosinte *(Zea mexicana)*, which is native to Mexico, Guatemala, and Honduras. Considerable cross-pollination between maize and teosinte has occurred during the course of their evolution. However, since the two species differ considerably in appearance, some researchers maintain that maize must have originated from a wild pod corn that is now extinct. The first maize cobs known to exist are about 7000 years old and were found in a cave in Mexico.

By the time the Europeans reached the Americas, maize had attained its modern form and was used as a staple food throughout the western hemisphere. Maize spread rapidly to Europe, Africa, and Asia with the explorers of the 16th and 17th centuries.

Today, nearly 40 % of the total world production of maize is produced in the United States, where the average yield is 7.5 t/ha. Much of the maize grown in developed countries is used for animal feed. Africa produces about 6 % of the total world production, most of which is for human consumption. In West and Central Africa, the average yield is about 1 t/ha.

The maize plant has a remarkable productive potential. In nine weeks, a single seed develops into a plant 2.5-3.5 m high. Two months later, it can produce 600 to 1000 seeds.

The maize plant described in this document is representative of a tropical variety, flowering in 55-60 days and maturing in 115 days.

However, considerable variation exists among varieties in morphology and growth habit. For example, an early-maturing tropical variety may attain a height of only 1 m, flowering in 45-50 days and reaching maturity in 90 days. Furthermore, environmental factors greatly influence the relative length of the various growth stages.

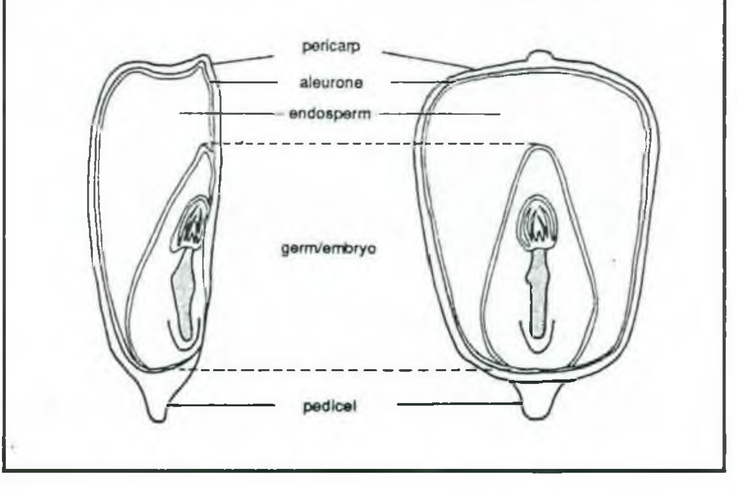
The structure of a maize kernel is typical of the grass family (Fig. 1). The kernel is a hard, one-seeded fruit called a **caryopsis.** It consists of:

- pericarp,
- endosperm,
- germ/embryo.

Pericarp. The pericarp is a protective outer layer, derived from maternal tissue.

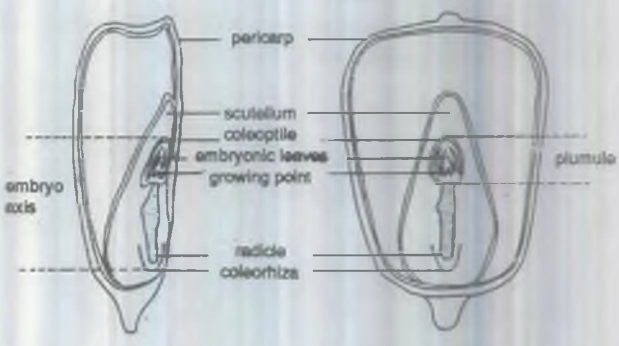
Endosperm. The endosperm constitutes the major portion of the kernel (about 82-84 % dry weight), and serves as energy reserve for the growing seedling. The endosperm is composed of about 88 % starch and 8 % protein.

Fig. 1. Maize kernel.



There are two types of endosperm: flinty (hard) and floury (soft). The distribution of flinty and floury endosperm depends on the variety and on climatic conditions. Dent varieties have flinty endosperm on the sides of the kernel with a central core of floury endosperm. The floury portions shrink upon drying, causing the tip of the kernel to become depressed or dented. The outermost layer of the endosperm is called the **aleurone**. The aleurone layer produces enzymes, which digest starch to form sugars. The sugars are used as energy for the developing seedling.

Fig. 2. Maize germ/embryo.



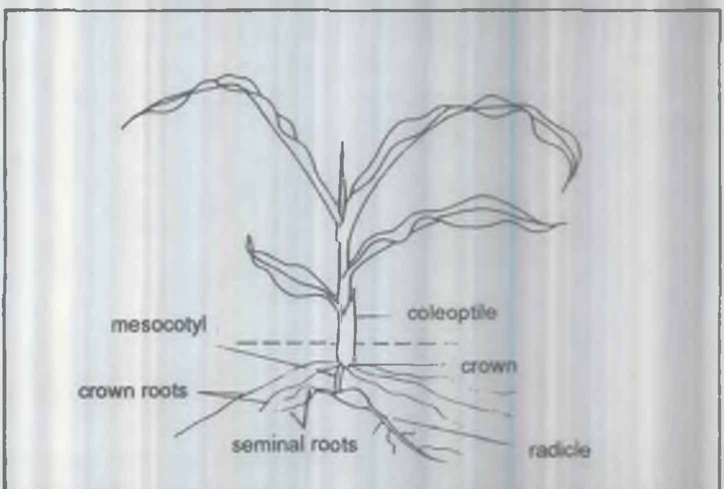
Germ/embryo. The germ or embryo comprises 10-12 % of the dry weight of the kernel. It consists of **embryo axis** and **scutellum** (Fig. 2). The scutellum helps the seedling in digesting and absorbing the starch from the endosperm. The embryo axis contains both the shoot and root of the kernel. The shoot consists of 5-6 **embryonic leaves**, the **growing point** (apical meristem), and a protective sheath for the growing shoot, called the **coleoptile**. The embryonic leaves and the stem are collectively called the **plumule.** The root end of the embryo axis contains the **radicle** (first root), several lateral root initials, and a protective sheath called the **coleorhiza**.

Germination. As soon as the seed absorbs water, certain chemical changes occur. The aleurone layer releases enzymes, which digest the endosperm starch into sugar, thereby providing energy for seedling growth.

The radicle elongates first, emerging from the seed coat. Then the shoot elongates and the coleoptile breaks through the seed coat. Elongation of the first internode (**mesocotyl**) pushes the coleoptile upward towards the soil surface. The coleoptile emerges from the soil 6-10 days after planting and soon ceases to grow. Sunlight at the soil surface stimulates the plumule to grow and break through the coleoptile.

In addition to the radicle, the young seedling (Fig. 3) develops several lateral roots called **seminal roots**. The initials of these seminal roots are already present in the embryo. Although the seminal roots make up a small proportion of the total root mass, they play an important role in anchoring the seedling and providing water and nutrients for initial growth. The main root system develops from the crown, which is located just below the soil surface. The **crown roots** develop shortly after the seedling emerges.

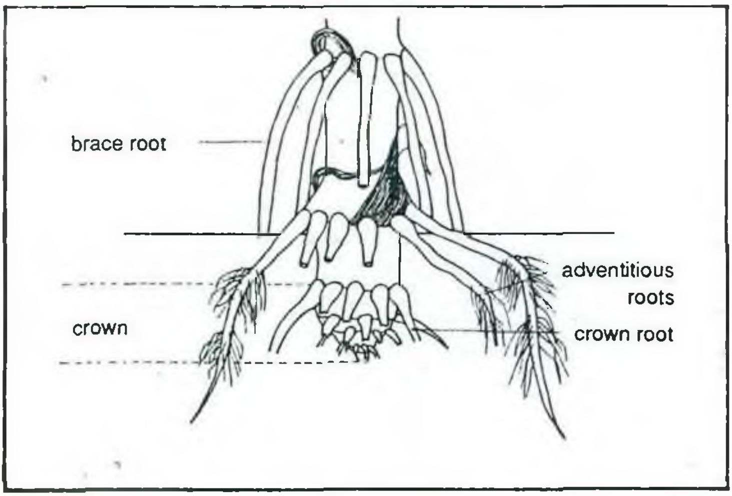
Fig. 3. Maize seedling two weeks after planting.



Vegetative growth includes stems, leaves, and roots.

Stems. The stem consists of nodes and elongated internodes. About eight nodes and internodes remain condensed underground, forming the **crown** (Fig. 4). The lower nodes of the stem form lateral branches, and roots that originate from stem tissue, called **adventitious roots**. The lateral branches may develop into tillers. The tillers are often shorter than the main stem, but in some environments tillers resemble the parent plant.

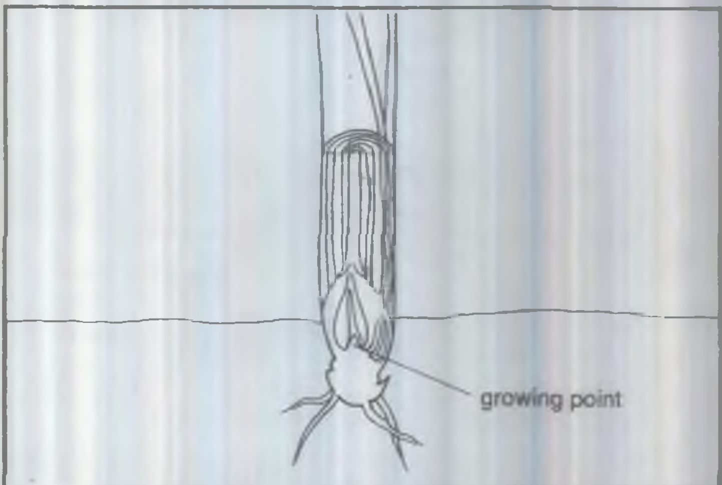
Fig. 4. Crown.



The upper nodes develop lateral branches that become either functional or rudimentary ear shoots. All branches form terminal inflorescenses, which can be male (tassels) or female (ear shoots).

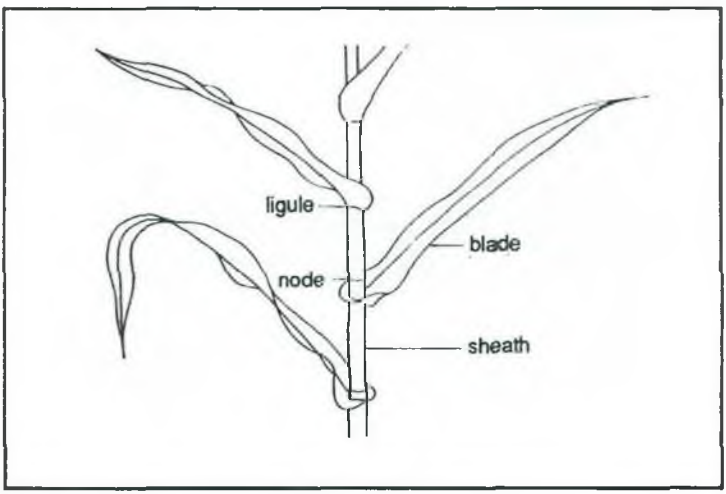
The **growing point** of the stem is located at the very tip of the stem (Fig. 5). *It remains underground for the first 3-4 weeks after planting.* When the growing point is below ground, a plant that is broken off at ground level can still regenerate a new plant. A plant that is broken below the growing point will not regenerate.

Fig. 5. Growing point.



Leaves. A single leaf grows from each **node**. The leaves extend from opposite sides of the plant in an alternating pattern. Each leaf consists of **leaf sheath**, **blade**, and **ligule** (Fig. 6). The ligule marks the point of extension of leaf blade from the stem. The leaf is connected to the stem below the ligule, where the leaf sheath is attached to the node. The leaf sheaths support the plant before the internodes begin to elongate, while the growing point is still below the ground.

Fig. 6. Maize leaves.



All leaves are initiated within the first 4-5 weeks after planting. As the internodes elongate, a 'new' leaf emerges from the whorl once every three days, producing a total of 20-23 leaves, depending on the genotype and the climate. The first five to seven leaves drop off at an early stage. The last leaves emerge shortly before tasseling.

Roots. **Adventitious roots** grow from the nodes that constitute the **crown** and from successive nodes near the ground (Fig. 4). By the eighth week, the fibrous root system may be well developed, extending into the area between rows and reaching 45 cm in depth. Cultivating between the rows at this stage can damage the plants.

The roots grow laterally in the upper soil and then turn vertically downwards (Fig. 7).

Fig. 7. Maize roots.

As the plant grows, individual roots may reach a depth of 2.5 m in good soil. Roots that originate from nodes above the ground are called **brace roots** (Fig. 4). Most brace roots form after tasseling and are concentrated in the surface soil.

4 Flowering and fertilization

The maize plant is monoecious, bearing male flower in the tassel and female flowers on the lateral ear shoots of the same plant.

Tassels. Approximately 30 days after planting, when the stem is only 2 cm long and the plant just knee-high, the tassel is initiated. Soon afterwards, internodes elongate and roots grow rapidly. Fifty days after germination and several days before pollen-shed, the top internodes elongate and the **tassel** emerges from the leaf whorl (Fig. 8).

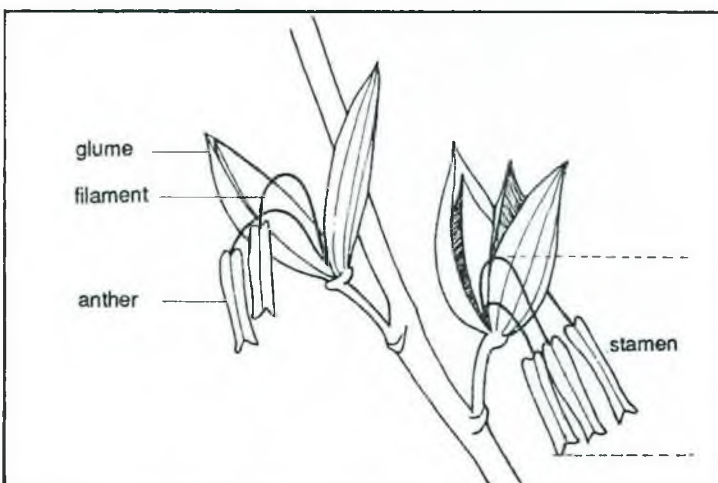
Fig. 8. Maize tassel.

Pollen is produced in the male **spikelets** of the tassel. Each spikelet consists of a pair of flowers (**florets**) enclosed in two large **glumes** (Fig. 9). The florets contain **stamens** which produce the pollen grains. Stamens are made up of **anthers** and **filaments**. Under favorable conditions the anthers emerge; generally mid-morning. The anthers break open at the tips, resulting in pollen-shed (anthesis).

The pollen does not usually move far unless there is adequate wind to promote cross-fertilization. Under unfavorable conditions, pollen-shed ceases.

The first spikelets open on the central axis of the tassel. The last spikelets shed pollen at the base of the tassel. Most tassels shed pollen for 5-8 days, with peak pollen production around the third day.

Fig. 9. Spikelet.



A vigorous maize plant can produce 2-5 million pollen grains, so the quantity of pollen is rarely a limiting factor in maize production.

Ear shoots. Ear shoots are initiated 6 to 8 nodes below the tassel and at lower nodes. Although buds occur at numerous nodes, only the top one or two ear shoots become functional.

The internodes on lateral branches bearing the female inflorescence are shortened, so that the **husk leaves** overlap and cover the developing ear (Figs. 10 and 11). Because the female spikelets occur in pairs, maize ears always have an even number of rows. Each spikelet contains one fertile ovule. A typical maize ear has 750-1000 ovules or potential kernels.

Fig. 10. Ear with silks.

Each ovule produces a **silk** (style) which is stigmatic (receptive for pollen germination) for most of its length. The maize style is longer than that of any other species in the plant kingdom. The first silks to emerge from the husk are those from the base of the ear.

Under favorable conditions, silks emerge 1-3 days after anthesis and remain fertile for about one week. Harsh weather can cause drying of the silks or delay silk emergence. Poor "nicking" (lack of synchrony of anthesis and silk emergence) results mostly from delayed silk emergence.

Silks are covered with moist, sticky hairs for catching pollen. Pollen grains germinate within a few minutes after reaching the silks. The pollen tubes grow down the silks in 12-28 h to fertilize the ovules.

5 Grain filling

Kernels are arranged in even numbers of rows along the **rachis** or **cob** of the ear. Several husk leaves protect the ear from environmental effects, such as disease infection (Fig. 11). Grain filling consists of several stages:

- blister stage,
- milk stage
- soft-dough and hard-dough stages.

Blister stage. Following fertilization, the silks wilt and turn brown. Carbohydrates and nutrients rapidly accumulate in the developing kernels. The "blister" stage begins about 10 days after flowering, when kernels appear shaped like small blisters.

Fig. 11. Maize ear at maturity.

Milk stage. The "milk stage" begins about three weeks after flowering. The kernels have a high sugar content at this point and are most suitable for consumption as fresh maize. Following the milk stage, the sugar content decreases and the starch content increases. Also, water content decreases as dry matter content increases. The "milk line" becomes apparent on the side of the kernel opposite the germ approximately 40 days after flowering. It separates the mature, starchy area from the milky region near the base of the kernel. The milk line moves toward the base of the kernel as the grain continues to mature.

Soft-dough and hard-dough stages. The last phases of the grain-filling period are sometimes divided into two stages, the "**soft-dough**" stage and the "**hard-dough**" stage. In a dent variety, the soft-dough stage corresponds to the time when 50 % of the kernels have started to dent. The hard-dough stage is reached when 90 % of the kernels have started to dent. Vegetative plant tissues senesce in the late grain-filling stages as carbohydrates and nutrients are translocated to the developing kernels.

By about seven weeks after flowering, the embryo has reached full size. By the following week, the kernel's maximum dry weight has been attained and the kernel moisture content is about 35 %. When the transport of assimilates to the kernel ceases, a "black layer" (abscission layer) forms at the base of the kernel. The kernels at the tip of the ear are the first to reach black layer, while those at the base mature last.

The ear is considered to be physiologically mature when 75 % of the kernels in the central part of the ear have reached the black layer. Another way to determine whether the ear is mature is by looking for the milk line. When the milk line is no longer present, the ear is physiologically mature.

The kernels at the tip of the ear are smallest because they are pollinated last and mature first, and therefore have less time to accumulate dry matter.

Kernels continue to lose moisture after physiological maturity. Variety and weather conditions determine the rate of drying. Mature kernels do not require a dormancy period. They can germinate as soon as growing conditions become favorable. However, grains must be well-dried to maintain viability in storage.

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