

# THE MAIZE SEED

## ANATOMY OF THE MATURE MAIZE SEED

The maize kernel is classified botanically as a caryopsis. In consequence it is a fruit composed by one seed and the remnants of the seed coats and nucellus and is permanently enclosed in the pericarp. The kernel is attached to the ear by the pedicel which remains attached to the base of the kernel.

### **PERICARP**

The pericarp consist in the transformed ovary wall that covers the seed and acts as a protection for the embryo and endosperm. It takes the place of the seed coats or integuments in the ordinary seeds, which in maize are reduced to unnoticeable remnants in the mature kernel. A thin, suberized nucellar membrane derived from the outer epidermal wall of the nucellus persists as a continuous covering between the aleurone and the pericarp.

### **ENDOSPERM**

The endosperm form most of the volume and weight of the kernel. It can be divided into three parts: starchy endosperm, aleurone layer and basal transfer layer.

#### **Starchy endosperm**

The central endosperm is formed by cells filled basically with starch granules and also by protein bodies. Cells in the starchy endosperm undergo a programmed cell death process at the end of the seed development so, in mature seed, it is composed by lifeless cells.

#### **Aleurone layer**

It consists in one celled layer of cells in contact with the pericarp that remain active until maturation and that accumulate basically lipids and storage proteins, but few starch. They play an important role during maturation.

#### **Basal transfer later**

At the base of the endosperm, the cells in contact with the pedicel are modified as conducting cells and apparently serve for transport the food from the mother plant to the embryo surrounding region. Vascular tissue does not extend beyond the pedicel, so direct transport is not possible.

### **EMBRYO**

The embryo is located in one face of the basal part of the kernel. Mature embryo is composed by a central embryo axis and the scutellum.

## **Embryo axis**

Embryo axis is formed by the primary root, protected by the coleorhiza, and the stem tip with five or six short internodes and leaf primordia (plumule) , protected by the coleoptile.

### Coleoptile

Is the first true leaf and is modified to act as a protective covering for the plumule or first bud of the plant which grow throughout the soil during germination.

### Plumule

It consists of the part of the stem above the coleoptilar node and includes the shoot apical meristem and four or five leaf primordia rolled up inside those below it, forming a cone inside the coleoptile.

## **Scutellum**

It is supposed to be the single cotyledon in the monocotyledoneus embryos. It is attached to the embryo axis in the scutelar node. It acts as a food storage organ and serves to digest and transport the endosperm nutrients during germination. It consists of four different tissues:

### Epithelium

A single layer of cylindrical, densely cytoplasmic cells bordering the starchy endosperm.

### Parenchyma

It forms the major part of the scutellum. It is formed by short cylindrical cells thick walls that contain a nucleus, dense cytoplasm, some starch granules, and lipid bodies.

### Epidermis

A single layer of cells bordering the scutellum next to the embryo axis.

### Provascular tissue

They are connected to the embryo axis vasculature in the scutelar node and then extend to the scutellum parenchyma.

### Mesocotyl

It is the part of the embryo axis between the coleoptilar and the scutellar node. It growth quickly during germination and serves to elevate the coleoptile to the soil surface.

### Primary root

Is enclosed in the coleorhiza and begins to grow soon after imbibition. usually, two or more adventitious seminal roots are present in mature kernels at the base of the first internode of the stem.

## **KERNEL DEVELOPMENT**

When the pollen grain attaches the style, it germinates and grow. The sperm nucleus fuses the egg nucleus to form the zygote and the generative nucleus unites the two polar nuclei, forming the endosperm.

## **EMBRYO DEVELOPMENT**

Embryogenesis is the process by which a single-celled zygote develops into a mature embryo. Although embryogenesis is a continuous process, for clarity, it is usually divided into phases in which a certain process prevails over the others. Usually, embryogenesis is divided in three phases: pattern formation, maturation and late embryogenesis.

### **Pattern formation**

The embryo (and seed) development in maize starts with a double fertilization event. One sperm cell fuses with the egg cell whereas the second sperm cell fuses with the binucleate central cell of the embryo sac to give rise to the endosperm. Maize seed is also composed by a seed coat, the pericarp, or maternal origin.

The zygote first division takes place about 40 hours after pollination and is asymmetric, generating a small apical and a large basal cells. The basal cell forms the suspensor, which is the connection to the maternal tissue, and the small apical cell develops to the embryo proper. Both structures enlarge through ongoing cell division but cells derived from the apical small cell remain small and with dense cytoplasm, whereas the cells derived from the basal one divide into large cells with vacuoles. The embryo proper initially forms an ovoid structure of undifferentiated cells. At this stage, cells in the outer part of the embryo proper differentiate from the others giving rise to an epithelium called protoderm. Protoderm cells have a large nucleus in a central position, a high frequency of polysomes, a low number of vacuoles and the absence of starch granules.

At about this stage division rate of embryo proper cells become much higher than cells in the suspensor, and the embryo enlarges, but not uniformly. Cells opposite to the developing endosperm remain small and dense and cells next to the endosperm start to enlarge. The smaller cells will produce the embryo axis whereas the enlarged ones will produce the scutellum. This differentiation determines that the embryo shifts to a bilateral symmetry.

Next, some of the dense cells in the embryo proper increase their cytoplasmatic density producing the shoot apical meristem (SAM). Next, some of the dense cells in the embryo proper increase their cytoplasmatic density producing the shoot apical meristem. SAM cells are encircled by the coleoptilar ring, a group of cells that will develop into the coleoptile, surrounding the SAM.

In maize, SAM starts to produce leaves primordia during embryo development, before germination. The first primordium is always produced at the basal face of the SAM, next to the coleptilar ring. At maturity, 5 or 6 leaf primordia are present, protected within the coleoptile for emergence through the soil.

At the same time, the primary root elongates and differentiates, producing the characteristic root histology including central pith, vascular elements, endodermis and cortex. Cells surrounding the RAM form the coleorhiza and protect it during root emergence.

### **Maturation**

During this phase the embryo increases in size and accumulates storage products as lipids and proteins. This takes place especially in the scutellum, which increases greatly in size. At the same time, suspensor degenerates through programmed cell death process.

### **Desiccation**

About 45-50 days after pollination the embryo contains 5-6 leaf primordia, a fully differentiated root primordia is present and one or two secondary root primordia emerge next to the coleoptilar node. RAM is protected by a coleorhiza and the coleoptile is fully developed. Embryo cells contain a great quantity of storage products, in special in the scutellum. A provascular system has developed in the embryo axis and in the scutellum through the scutellar node. At this stage the embryo stops its development and starts to accumulate proteins that will protect it from desiccation and prepare it to the dormancy. The embryo loses water and becomes dormant.

## **ENDOSPERM DEVELOPMENT**

The endosperm development begins by rapid nuclear divisions generating about 256 nuclei. Cell walls begin to form around the nuclei about 4 days after pollination (dap) and by 6 dap the endosperm is completely formed by uninucleate cells. By 12 dap cells fill the central endosperm.

Cells above the pedicel become differentiated and function as a conducting tissue called the basal endosperm transfer layer (BETL), that actively move nutrients into the embryo area. Vascular tissue does not extend beyond the pedicel. By kernel maturation these cells degrade into a narrow band of crushed cells that accumulate a brown pigment (black layer).

The outer cell layer differentiates to form the aleurone. Initially, cell divisions occur in all the endosperm, but later, cell divisions become restricted to the peripheral region. After 16 dap the endosperm growth continues by cell enlargement and cells accumulate starch granules and protein bodies. Aleurone cells begin to differentiate at about 15 dap and accumulate oil bodies and protein bodies, but few starch.

Immediately outside the aleurone layer cells a very thin membranous tissue is present called seed coat, which is the remains of the integument tissue of the ovary.

## PERICARP DEVELOPMENT

Soon after pollination the ovary wall begins to transform into pericarp. It increases its size by cell division and expansion, and the cell walls gradually thicken in the outer part of the pericarp.

