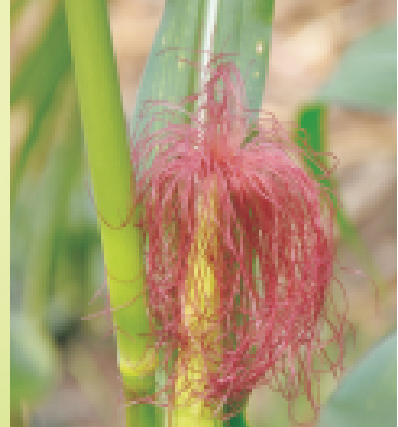


# MAIZE BIOLOGY: AN INTRODUCTION



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## **Preface**

Maize is one of the world's important food crop, which supplies >5% dietary energy. The wider adaptability and high yield potential of maize and its utility as food, feed and forage crop signifies the importance of maize. In recent years, there has been tremendous increase in its acreage and production because of its usage in both food as well as non food industrial products. Maize being a highly cross pollinated crop requires special efforts to maintain its genetic purity. It is a tall, determinate, monoecious, annual plant, produces large, narrow, opposite leaves, borne alternatively along the length of stem. All maize varieties follow same pattern of development, although specific time and interval between stages and total number of leaves developed may vary between different hybrids, seasons, time of planting and location. The basic information of maize about its origin, progenitors, developmental stages, types of corn, pollen viability, anthesis and silking are the foremost requirement to maize researchers for efficient and effective maize improvement programme. In this bulletin we have tried to compile the information about origin and evolution of maize, its growth stages, types, flowering (including floral biology), pollen viability, isolation distance, time for fertilization and importance of anthesis-silking interval. This will help the researchers and scholars to identify the right stage of nutrients management, pollination and maintenance of genetic purity through hand pollination and or by maintaining isolation distance. We would like to continue the activity of update as and when further new information will receive either through knowledge gain or through comments from the readers.

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## 1. Introduction

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies and uses. Beside this maize have many types like normal yellow/white grain, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, *etc.* Apart from this, maize is an important industrial raw material and provides large opportunity for value addition.

Globally, it is cultivated on more than 160 m ha area across 166 countries having wider diversity of soil, climate, biodiversity and management practices. Maize contributes maximum among the food cereal crops i.e. 40 % annually (> 800 mt.) in the global food production. Among the world maize growing countries, USA is the largest producer of contributes nearly 35% of the total maize produced, followed by China with more than 20% production with same acreage as of USA. Maize is the driver of US with highest productivity ( $\geq 10 \text{ t ha}^{-1}$ ) which is double than the global ( $5.3 \text{ t ha}^{-1}$ ). Whereas, productivity of India is just half than the world productivity.

In India, maize is the third important food crop after rice and wheat. According to latest data (2010-11), it is being cultivated on 8.6 m ha with 80% area during *Kharif* season. The current maize production is 21.7 mt, with an average productivity of 2.5 t/ha. Despite maize being predominantly rainfed crop its productivity is more than rice which is mainly grown under assured irrigated/rainfed conditions. Maize contributes nearly 9 % in the national food basket and more than 400 billion to the agricultural GDP at current prices. In addition it generates employment to over 1000 million man-days at the farm and downstream agricultural and industrial sectors. Maize is primarily used for feed (60 %) followed by human food (24%), industrial (starch) products (14%) beverages and seed (1% each). Thus, maize has attained an important position as industrial crop because 75% of its produced is used in starch and feed industries. In India, maize is predominantly cultivated as rainfed crop but due to focused research on single cross hybrids

## 2. Taxonomy, Origin and Evolution

### Taxonomy

Maize belongs to the tribe Maydeae of the grass family *Poaceae*. “*Zea*” was derived from an old Greek name for a food grass. The genus *Zea* consists of four species of which *Zea mays* L. is economically important. The other *Zea sp.*, referred to as teosinte, is largely wild grass native to Mexico and Central America. The number of chromosomes in *Zea mays* is  $2n = 20$ . Tribe Maydeae comprises seven genera which are recognized, namely Old and New World groups. Old World comprises *Coix* ( $2n = 10/20$ ), *Chionachne* ( $2n = 20$ ), *Sclerachne* ( $2n = 20$ ), *Trilobachne* ( $2n = 20$ ) and *Polytoca* ( $2n = 20$ ), and New World group has *Zea* and *Tripsacum*. It is generally agreed that maize phylogeny was largely determined by the American genera *Zea* and *Tripsacum*, however it is accepted that the genus *Coix* contributed to the phylogenetic development of the species *Zea mays*.

Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Poales
Family	Poaceae
Genus	<i>Zea</i>
Species	<i>mays</i>

The transformation of maize from teosinte involved evolutionary forces such as mutation, hybridization, genetic drift and selection aided by the activities of human beings, who selected useful variants out of large populations of teosinte and concentrated them into isolated evolutionary pools. This resulted in the differentiation of maize into large number of races. The races gradually got adapted to different agro-climatic regions in the America away from the centre of origin. On the basis of morphological data, several authors suggested that there has been extensive gene flow between maize



*Zea mays ssp. parviglumis*:  
Basal branching type.  
(Note: Proliferation of tillers  
at the base of plant.)

*Z. mays L. spp. maxicana*:  
Lateral branching type  
(Note: Branching is lateral,  
with each branch terminating  
in a tassel.)

**Fig. 2.1** Plant habit as an evidence for double origin of maize

Source: A line drawing adapted from a painting by Walton C. Galinat (1988).

and with no visible leaf collar are not included. For example, a plant with 3 collars would be called a V3 plant, however, there may be 6 leaves showing on the plant.

## VE - Emergence

Coleoptile reaches the soil surface and exposure to sunlight causes elongation of the coleoptile and mesocotyl to stop. The growing point, located just above the mesocotyl, is about 0.75 inches below the soil surface. Embryonic leaves rapidly develop and grow through the coleoptilar tip. Seminal root growth begins to slow and nodal roots are initiated at the crown. Weed control at this stage will result in little yield loss, but late-emerging weeds may produce substantial seed, increasing the soil seed bank.



## V1 - First leaf collar

Lowermost leaf (short with rounded tip) has a visible leaf collar. Nodal roots begin elongation. Again, weed control at this growth stage will result in little yield loss, but seed from weeds that emerge later in the growing season may contribute to the soil seed bank if a residual herbicide has not been applied.



## V3 - Third leaf collar

The growing point remains below the soil surface as little stalk elongation has occurred. Lateral roots begin to grow from the nodal roots and growth of the seminal root system has ceased. All leaves and ear shoots that the plant will produce are initiated at this stage. Since the growing point remains below the soil surface, cold soil temperatures may increase the time between leaf stages, increase the total number of leaves formed, delay tassel formation, and reduce nutrient uptake.







## 4. Botanical Features

Maize is a tall, determinate annual C<sub>4</sub> plant varying in height from <1 to >4 metres producing large, narrow, opposing leaves, borne alternately along the length of a solid stem. The botanical features of various plant parts are as follows:

**Root:** Normally maize plants have three types of roots, i) seminal roots - which develop from radical and persist for long period, ii) adventitious roots, fibrous roots developing from the lower nodes of stem below ground level which are the effective and active roots of plant and iii) brace or prop roots, produced by lower two nodes. The roots grow very rapidly and almost equally outwards and downwards. Suitable soils may allow corn root growth up to 60 cm laterally and in depth.

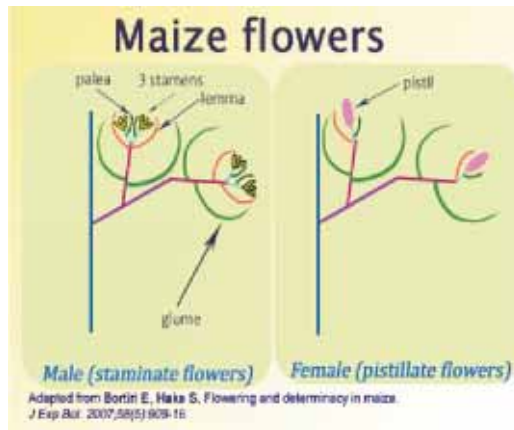
**Stem:** The stem generally attains a thickness of three to four centimeters. The internodes are short and fairly thick at the base of the plant; become longer and thicker higher up the stem, and then taper again. The ear bearing internode is longitudinally grooved, to allow proper positioning of the ear head (cob). The upper leaves in corn are more responsible for light interception and are major contributors of photosynthate to grain.

**Flower:** The apex of the stem ends in the tassel, an inflorescence of male flowers and the female inflorescences (cobs or ears) are borne at the apex of condensed, lateral branches known as shanks protruding from leaf axils. The male (staminate) inflorescence, a loose panicle, produces pairs of free spikelets each enclosed by a fertile and a sterile floret. The female (pistillate) inflorescence, a spike, produces pairs of spikelets on the surface of a highly condensed rachis (central axis, or “cob”). The female flower is tightly covered over by several layers of leaves, and so closed in by them to the stem that they don't show themselves easily until emergence of the pale yellow silks from the leaf whorl at the end of the ear. The silks are the elongated stigmas that look like tufts of hair initially and later turn green or purple in color. Each of the female spikelets encloses two fertile florets, one of whose ovaries will mature into a maize kernel once sexually fertilized by wind-blown pollen.

As the internodes of the shanks are condensed, the ear remains permanently enclosed in a mantle of many husk leaves. Thus the plant is unable to disperse its seeds in the manner of a wild plant and instead it depends upon human intervention for seed shelling and propagation.

The explanation for each maize male and female floral organ has been given below:

**Tassel:** inflorescence of male flowers; the tassel consists of several long, indeterminate branches bearing short determinate branches (spikelet pairs) that bear two spikelets (compact auxiliary branches of grass inflorescence, that in maize consists of two bracts subtending one reduced male flower).



**Stamen:** pollen-producing reproductive organs which are collectively referred as androecium.

**Stalk:** also **filament**; the part of the stamen on which **anther** develops.

**Anther:** the terminal part of a stamen in which the pollen grains are produced.

**Microspore:** smaller of the two types of spore produced in heterosporous plants; develops in the pollen sac into a male gametophyte.

**Male gametophyte:** microspores divide twice to produce 3 celled pollen grain/tube (a male gametophyte); two of the cells are sperm; other is called **vegetative cell**, or **tube cell**.

**Sperm cell:** two sperm cells are produced; one sperm cell fuses with the **egg** resulting in **zygote**; other sperm cells fuses with **central cell** giving start to development of triploid tissue called **endosperm** which surrounds the embryo and serves an absorptive/nutritive function in seed.

compatible. There is no asexually reproductive maize. Cell/tissue culture techniques can be used to propagate calli and reproduce tissues or plants asexually.

## Pollination and Fertilization

Formation of the female flowers or cobs is the first reproductive stage and occurs 2-3 days after tasseling stage. This stage begins when any silks are visible outside the husk. These are auxillary flowers unlike tassels that are terminal ones. Pollination occurs when these new moist silks catch the falling pollen grains. In maize, the pollen shed is not a continuous process and usually begins two to three days prior to silk emergence and continues for five to eight days. The silks are covered with fine, sticky hairs which serve to catch and anchor the pollen grains. Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions are favourable. Under favourable conditions, pollen grain remains viable for only 10 to 18 hours. Cool temperatures and high humidity favour pollen longevity. Under optimal conditions the interval between anthesis and silking is one to two days. Under any stress situation this interval increases. Fertilization occurs after the pollen grain is caught by the silk and germinates by growth of the pollen tube down the silk channel within few minutes of coming in contact with a silk and the pollen tube grows the length of the silk and enters the embryo sac in 12 to 28 hours. Pollen is light and is often carried considerable distances by the wind. However, most of it settles within 20 to 50 feet. Pollen of a given plant rarely fertilizes the silks of the same plant. Under field conditions 97% or more of the kernels produced by each plant are pollinated by other plants. Fertilization of ovules begins about one third of the way up from the base of the ear.

Maize, being a cross-pollinated crop, various reproductive isolation methods are used by plant breeders and by seed producer to produce genetically pure seed. The isolation of crops using separation distances and physical barriers are common techniques for restricting gene flow and ensuring seed purity for maize seed production. Various experimental practices mostly used to maintain reproductive isolation maize are:



same genus (interspecific) and between genera (intergeneric) first requires the formation of a viable intermediate hybrid that is capable of producing fertile progeny that can survive into the next generation. Assuming sexual compatibility exists, other factors also contribute to the likelihood of hybridization: proximity of the crop and related species to each other; environmental conditions; and overlapping flowering periods. The introgression of genes from maize to other plant species may require several generations of recurrent backcrossing.

## Seed dispersal

Seed dispersal of individual kernels naturally does not occur because of the structure of the maize ears. Maize, as a thoroughly domesticated plant, has lost all ability to disseminate its seeds and relies entirely on the aid of man for its distribution. The kernels are tightly held on the cobs. In case ears fall to the ground, so many competing seedlings emerge then the likelihood of any seedlings to grow till maturity is extremely low.

## Corn seed anatomy

**Grain:** The individual maize grain is botanically a caryopsis, a dry fruit containing a single seed fused to the inner tissues of the fruit case. The seed contains two sister structures, a germ which includes the plumule and radical from which a new plant will develop, and an endosperm which will provide nutrients for that germinating seedling until the seedling establishes sufficient leaf area to become autotrophy. The germ is the source of maize “vegetable oil” (total oil content of maize grain is 4% by weight). The endosperm occupies about two thirds of a maize kernel’s volume and accounts for approximately 86% of its dry weight. The endosperm of maize kernels can be yellow or



Image downloaded from [www.geochembio.com/biology/organism/maize](http://www.geochembio.com/biology/organism/maize)

## 5. Anthesis-Silking Interval (ASI)

Grain number is a major determinant of yield in maize as well as other crops and factors that contribute to improved grain set, especially under drought, are of great importance to increase crop production. In this crop, it was found that great improvements in yield could be achieved by selection under managed drought environments, within existing elite germplasm, i.e. genetic variation existed that had not been exploited by previous breeding activities for yield potential and disease tolerance. In maize, drought that occurs from the mid to late vegetative stage onwards does not affect the timing of tassel anthesis, but delays the process of ear silking. In segregating genotypes under drought (for the same anthesis date), a lengthening of the ASI period is an indicator of poor tolerance to drought. The reason for the silk delay is that, the drought-susceptible genotypes allocate less assimilate toward ear growth when the ears are quite small, and this is indicated quite well by a delay in silking (appearance of silks from the husk). Even if these silks are pollinated separately, many of the grains will abort, resulting in a low grain number per ear. Recurrent selection for low ASI, high fertile ear number per plant, small tassels and delayed senescence therefore resulted in substantial increases in partitioning to early ear growth and successful grain set. Poor timing of pollen shed itself can be an additional problem (Du Plessis and Dijkhuis, 1967), though in fields of maize, pollen supply is quite high for a long period due to slight variation in plant-to-plant timing of pollen shed. Substantial genetic variation has been found in tropical maize populations and recurrent selection for the ASI has been applied in these populations in Mexico, together with selection for yield and stay-green while preventing selection for earliness or drought escape and also maintaining gains for yield potential (Edmeades et al., 1999). This germplasm has also performed well under drought in southern and eastern Africa (Banziger et al., 2004) and across most drought prone locations in both tropical and temperate sites (Bruce et al., 2002). More recently, it has been shown that this drought tolerance is largely additive in nature, and so can be passed through to hybrid maize by developing drought tolerance on both sides of a pedigree (Betrán, 2003).



Generally, the kernels are smooth and rounded, and the ears are long and slender with a comparatively small number of rows or kernels. In temperate zones, flint corn often matures earlier, germinates better has more spring vigor, more tillers and fewer prop roots than dent strains.

### Flour Corn

This is one of the oldest types of corn, tracing back to the ancient Aztecs and Incas. American and Indians used to ground the soft kernels for flour. Floury maize types have soft starch throughout, with practically no hard, vitreous endosperm and thus are opaque in kernel phenotype. Kernels tend to shrink uniformly upon drying, so usually have little or no denting. When dry, they are easy to grind, but may mold on the mature ear in wet areas.

### Sweet Corn

In sweet corn, the sugary gene prevents or retards the normal conversion of sugar into starch during endosperm development, and the kernel accumulates a water-soluble polysaccharide called “phytoglycogen.” As a result, the dry, sugary kernels are wrinkled and glassy. The higher content of water-soluble polysaccharide adds a texture quality factor in addition to sweetness. Today, the standard sugary corns are being modified with other endosperm genes and gene combinations that control sweetness to develop new cultivars. As a result, growers must consider genetic type while making selections for planting. The genetic type is not readily identifiable by cultivar name alone. At least 13 endosperm mutants, in combination with sugary, have been studied for improving sweet corn. Except for sugary, the genes used in breeding act differently to produce the taste and texture deemed desirable for sweet corn. Major modifier genes of kernel sweetness are shrunken-2 (*sh2*) and sugary enhancer (*se*). In partial modifications, the sugary (*su*) kernels are modified by the segregation of major modifier genes such that about 25 percent of the kernels are double-mutant endosperm types possessing the enhanced benefits of the modifier. The addition of the sugary enhancer (*se*) gene along with one of the major modifier genes (e.g., *sh2*) will further modify some of the sugary kernels to about 44 percent double-mutant endosperm types.



## High-amylose corn

Amylomaize is the generic name for corn that has an amylose content higher than 50 percent. The endosperm mutant amylose extender (*ae*) was first observed by R. P. Bear in 1950, which increases the amylose content of the endosperm to about 60 percent in many dent backgrounds. Modifying factors alter the amylase contents as well as desirable agronomic characteristics of the grain. The amylose-extender gene expression is characterized by a tarnished, translucent, sometimes semifull kernel appearance. The starch from high-amylose corn is used in the textile industry, in gum candies (where its tendency to form a gel aids production), and as an adhesive in the manufacture of corrugated cardboard.



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