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Life Cycle of Maize Plant: From Seed-To-Seed

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During plant ontogeny a maize plant goes through various stages of growth and development, having distinct phonological and physiological characteristics. A standard system to define various developmental stages allows researchers and agriculturists to relate the problem, cultural practices and various physiological and phonological observations at specific growth stage. Since expression of various traits is governed by two factors, i.e. genetic makeup and environment, it helps in comparing the phenology and performance of a particular germplasm across the growing conditions and environments. The staging system employed in maize is broadly divided into two categories, i.e. vegetative (V) and reproductive (R) stages (lowa, 1984). Vegetative stage starts from coleoptiles emergence (VE) and further sub-divisions of stage-V is designated numerically as V1,V2, V3….Vn, where (n) represents the last leaf stage before tassel emergence (VT) in a specific genotype. The (n) is governed by genotype and environmental conditions. Similarly, the reproductive stage is also sub-divided as RO,R1,R2……R6 (physiological maturity). The two broad categories are further grouped into four major stages of crop growth, i.e.

1. Seedling emergence and early growth stage (VE and V1)
2. Vegetative stage (V2, V3…. Vn)
3. Flowering and fertilization (VT, RO and R1)
4. Grain filling and maturity (R2,R3…. R6)

The uppermost leaf whose collar is visible determines the particular stage of vegetative growth. Characteristically oval-shaped first leaf is a reference point for counting upwards to the topmost visible leaf collar. From V6 stage onwards the degeneration of lower leaves starts with increase in stalk and nodal root growth, and by the time of appearance of the collar of last leaf the lower 5-6 leaves might have already degenerated, and therefore, care must be taken while counting the leaves at later vegetative stages. (Zaidi *et al*, 2018)

Germination and Seedling Emergence: Healthy and well-preserved maize seeds usually possess high seed viability (95-100%) and fully matured and perfectly dried seeds (<15% moisture level) stored under favourable conditions may retain the viability for several years. It can be used up to four years without serious losses. However, after six years the seed viability usually begins to drop rapidly. Seed viability under storage is affected significantly when it is exposed to very low (freezing) or high temperature regimes with high moisture content in the seeds. Seed viability is also affected drastically due to infection with seed-borne or soil-borne pathogens.

Moist and warm soils which allow prompt germination are most suitable at the time of planting. Water is absorbed through seed coat and kernel begins to swell. Chemical changes activate growth in the embryo axis and if conditions continue to be favorable, the radicle elongates and emerges from the seed coat within 2-4 days. Thereafter, plumule also begins to elongate and additional leaves begin to from inside this part of the developing seedling. First seedling root is seen followed by several other seminal or seed roots, which serve to anchor the developing seedling and play an important role in water and nutrient uptake. However, they are not a permanent root system; the main root system originates later from the crown of the developing plant above the first root system. Between the point of attachment to the seed and crown is a tabular, white, stem-like part, called mesocotyl (first internode). Elongation of this structure is very important for emergence of the seedling (VE). With an average planting depth 2-3 inches, mesocotyl elongates about half the distance to the surface. Increase in length of the coleoptiles brings the leafy parts above ground. In case of very deep planting or when growing conditions are unfavourable, elongation of the mesocotyl may stop: in other cases the seedling loses orientation and grows in a corkscrew fashion, failing to emerge from soil.

Germination and seedling establishment is the first critical time in the life cycle of a maize plant. If soil is too cold, too wet, or too dry, germination may be slow or young seedling may die before it becomes established. Soil temperature has been found to be directly related to germination and emergence. Less than 100C temperature may completely inhibit the germination process. Nutrient shortage are not critical in the first few days, but as roots begin to take over the job of nourishing the young plant, shortages of major elements, especially phosphorous, can seriously affect the growth and development. A young plant is flexible in its requirements and has a high capacity to recover from early setbacks. This stage (when the growing point is still below ground) is most susceptible to damage by flooding, especially if temperature is high. (Zaidi *et al*.2018)

Vegetative Growth: Once the seedling is established, plants begin to create the root system and leaf structure. A single growing point at the tip of stem produces new leaves. Starting with embryonic leaves (5-6) a normal maize plant develops 20-23 foliage leaves. Generally, first 5-7 leaves are comparatively small and break off as the base of stalk elongates. Root system develops rapidly during this stage of growth. Seminal roots quickly lose their importance and the young plant is supported and nourished by permanent root system that begins to develop from crown. Depth of planting has only a slight influence on depth at which the main root system originates. Main root system continues to grow downwards and branch, and additional roots are produced in successive whorls from stem nodes above the crown. These joints from which the roots develop just below the soil surface correspond to the joints aboveground from which the leaves arise. By knee high stage (V7-V8 stage) roots may have penetrated to a depth of about 45 centimeters. At the time of tassel emergence, whorls of brace roots develop from the lower nodes end enter into the soil. Apart from anchorage, the brace roots can effectively absorb phosphorus and perhaps other nutrients. Brace roots branch profusely on the surface soil and, thus provide feeding roots in a soil zone that may have relatively few other active roots, late in the season.

Deficiency symptoms of various nutrients, especially phosphorus, potassium and zinc, are most likely to be seen during the vegetative development stage. Insects, wet weather, hail and other hazards also have their effect. However, a maize plant has an amazing capacity to recover from apparent injury during this stage, provided later conditions are favourable.

Floral Initiation and Development: In fact, the development of both male and female spikelet's follows similar systematic events, which results in unisexual male and female flower formation (Fig.1) approximately at 30 days after planting, when stem is about 2.0 cm in height, a remarkable and sudden change in the function of the growing point takes place when the plant has formed its full number of leaves. However, many of them are not yet visible and only 8-10 leaves can be seen externally. Growing point is rounded or hemispherical until now, elongates into a round tipped cylinder. The transition phase (2-3 days) is followed by the appearance of tiny bumps on the sides of the growing point. Within a few more days, the embryonic tassel has developed, which is recognizable. This is the time of rapid elongation of lower inter-nodes and extremely rapid vertical growth, placing heavy requirements on the root system to supply water and nutrients.

Maize ear is borne at the tip of lateral branch, which develops from the nodes below the tassel. Ear primordia begin to form on the side of the growing point shortly after (about 1 week) the tassel initiation. Although buds occur at many nodes, however, only top 2-3 ear shoots eventually from ears. However, in prolific genotypes, ears may develop at several nodes. Initiation of auxillary buds begins at the base of the stem and proceeds upwards. However, differentiation of buds into ear shoots from the uppermost bud towards the base of the plant. Ear shoot initiation occurs about 10 days after tassel initiation. Ear elongation stops first at lower nodes giving top ears more time to develop and accumulate assimilate. Internodes on lateral branches bearing the female inflorescence are shortened, which facilitate the husk leaves to overlap and cover the developing ear. Female spikelets are in pairs; therefore, maize ears always have an even number of rows. A typical maize ear has 500-750 ovules or potential kernels.

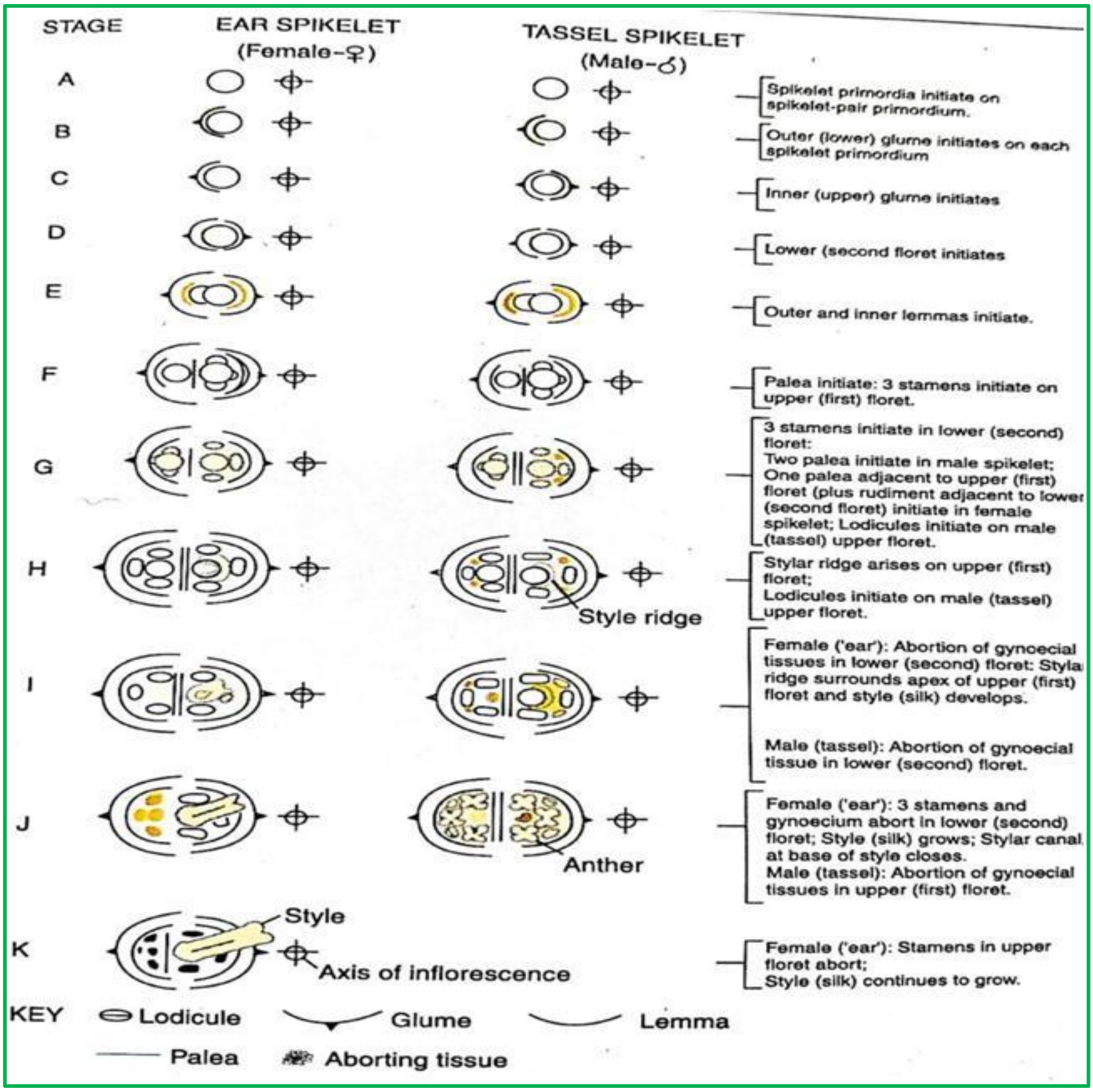

Fig 1: Development of male and female spikelet's in maize

All of the internodes, except the top 2-3 achieve full-elongation about a week before the beginning of pollen shed. The last few days, just before pollen-shed and silking are a time when the plant spends most of its energy to produce mature pollen, and to form the cob and ear structures. These two processes create very high requirements for proteins in which young tissues are especially rich. If growing conditions are unfavourable, especially if nitrogen is deficient, the size of the developing ear is reduced. Apparently within the control mechanism of the plant, tassel and pollen formation take priority over ear and silk formation and silk developments. Size of the ear is determined over about 3 weeks period starting about 6 weeks after the plant emerges . First, the number of rows of ovules (kernels) is determined, and then the maximum number of kernels per row is fixed, which develop silks. This stage is the most critical periods in the development of a maize plant. The high requirements for nutrients, water and the "building block" products of metabolism make any shortages or defects in function at this stage especially serious.

Pollination and Fertilization: By the time of pollination all major vegetative growth of the plant has already been completed. Leaves and stalks reach their maximum size and metabolic activity of the plant tissues is normally at its peak level. At anthesis, the lodicules swell to several times their earlier size and push the lemma and palea apart, which facilitate the anthers to be extruded by elongation of filaments. After extrusion, the anthers split-open near the tip through which pollen shedding takes place. Once started, the pollen shedding may continue for several days (usually 5-8 days). In general, pollen shed begins from a short distance below the central axis of the tassel, proceed both upwards and downwards and spread out over the whole tassel in succeeding days. And end in shedding from the tips and bases of the lower branches. It is not always a continuous process; rather it may stop when the tassel is too wet or too dry, and begins again when temperature and moisture conditions are favourable. On a typical mid-summer day the peak pollen shedding may stop completely before rain starts.

Maize is known to be a very efficient and profuse pollen shedder. It is, however, difficult to estimate accurate figure for the number of pollen grains produced by a vigorous maize tassel. It is estimated between 2-5 million from a full- sized maize tassel, which suggest that there are 2000-5000 pollen grains available to pollinate a single silk. Under favourable environment maize pollen remains viable only for about 18-24 hours after shedding. Shortage of pollen is rarely a problem for maize productivity, except under conditions of extreme heat or drought, which may cause high percentage of tassel blasting, or in the case where planned genetic sterility prevents pollen formation. The maize pollen is very light in weight, and therefore, it often travels a considerable distance, depending on wind speed, but most of it settles within 20 to 50 feet (6-15 meters).

A well-developed tropical maize ear shoot bears 750 to 1000 potential ovules, arranged in an even number of rows around the cob, which may vary from 12-20 rows and approximately 50 potential ovules per row. Each of these ovules produces a long cylindrical tube (the silk), which receives the pollen. In general, the first silks produced on a plant emerge from the enclosed husks 1-3 days after initiation of pollen shedding. The silks present near the base of the ear emerge first, and those from the tip appear last. Under favourable conditions, almost all the silks emerge within 3-5 days and get pollinated before the tassel stops shedding pollen. However, despite this overlap in the timing of pollen-shed and silking, maize being strictly a cross pollinated crop the pollen of a given plant rarely fertilizes silks of the same plant. Under field conditions, about 97% or more of the kernels produced by a plant are pollinated by the pollen produced by other plants in the field. Once the pollen grains fall o silks, they are tapped by small hairs and by the moist , sticky nature of the silk surface. Pollen grains germinate rapidly, producing a pollen tube that grows down through the length of the silk within 12-28 hours and enters the ovary. After entering in the embryo sac the end of the pollen tube ruptures and releases two sperms. The nucleus of one sperm fuse with egg nucleus forming zygote and in this way the diploid number of 20 chromosomes is restored to developing embryo. Other sperm nucleus fuses with the other polar nucleus with 30 numbers of chromosomes. With this double fertilization male parent contributes to both embryo and endosperm for the next generation. Usually, the first tube reaching the female embryo sac causes fertilization, and a new kernel begins to develop from this union.

Pollination and fertilization are the extremely critical stages in the life of a maize plant. Any type of unfavourable condition at his stage have drastic effects on maize yield, since a kernel which does not begin developing at this stage cannot start later, and an ear shoot which is not well-formed and fully-pollinated can never become a full-sized ear at maturity. The most critical mater at this stage is the heavy demand for water and nutrients, especially nitrogen, which is required for the tremendous physiological activity at this stage. One of the most important factors is poor synchrony between pollen-shed with silk emergence (poor nicking). Most of the time it is merely due to delayed silking, rather than delayed pollen shedding, which in turn may be traced to faulty ear-shoot development because of scarcity of some essential inputs such as –water/ nutrients. The first few days after fertilization is a very nutrient deficiencies, low light intensity or high population density, it may result in severe kernel abortion in the upper part of the ear, even though they are fertilized.

Kernel Development and Maturation: Union of male sperm nuclei with female eggs and polar nuclei gives the fertilized ovules (embryonic maize kernel). During the first few days after fertilization, no visible changes take place in the fertilized ear shoot, except that the silks turn brown and wilted. By the time the developing kernels appear as watery blisters (1.5-2.0 weeks after fertilization) cob reaches to its full length and diameter. In next two weeks, kernels grow very rapidly and at this stage, most of the physiological activities are directed towards food storage in the developing kernels. By the end of third week after pollination, kernels are filled with a milky fluid, high in sugars along with starch and protein-forming bodies. Up to his period, called lag phase, developing kernels have very poor access to stored assimilates, and therefore, completely dependent on current Until about end of fifth week, contents of the developing kernels undergo remarkable changes. Sugars rapidly disappear, and are replaced first by gummy dextrin, and shortly thereafter by dry starch. Dry matter increase with corresponding loss of moisture in kernels. By end of the seventh week of kernel development, embryo has nearly reached to its full size, food storage slows, and the kernel reaches near maturity. By end of eight week after pollination, kernels usually have reached to the maximum dry weight . this stage is called physiological maturity. Difference in length of growing season between early and late maturity cultivars is usually due to number of days from planting to silking, rather than the days from silking to maturity supply (Fig.2).

Appearance of the black layer (abscission layer near the tip of al mature kernels) is an indication that the transport of photosynthetic into the kernel has stopped. Black layer can be easily observed by either cutting the mature kernel length- wise into half or by breaking the tip of the kernel. Black layer is caused by the collapse and compression of several layers of cells near the tip of the kernel. Collapse of these closes off the conducting tubes, stop translocation and form abscission layer, an individual ear is considered to be mature when at least 75% of the kernels in the central part of the ear consist of black layer. Rate of moisture loss from the mature kernel after physiological maturity depends more on the prevailing weather than any other factor. Under favourable conditions, this stage is less critical in its effects on yields than the two preceding stages of development. The number of ears and kernels per ear has already been fixed. However, under unfavourable conditions such as moisture shortages, lack of nutrients, disease attack, or their severely adverse conditions significantly affect grain filling, especially for the kernels present at tip of the ear. In this way the conditions during these perils determine kernel size, whereas conditions in earlier growth stages mainly determine the number of ears and kernels.

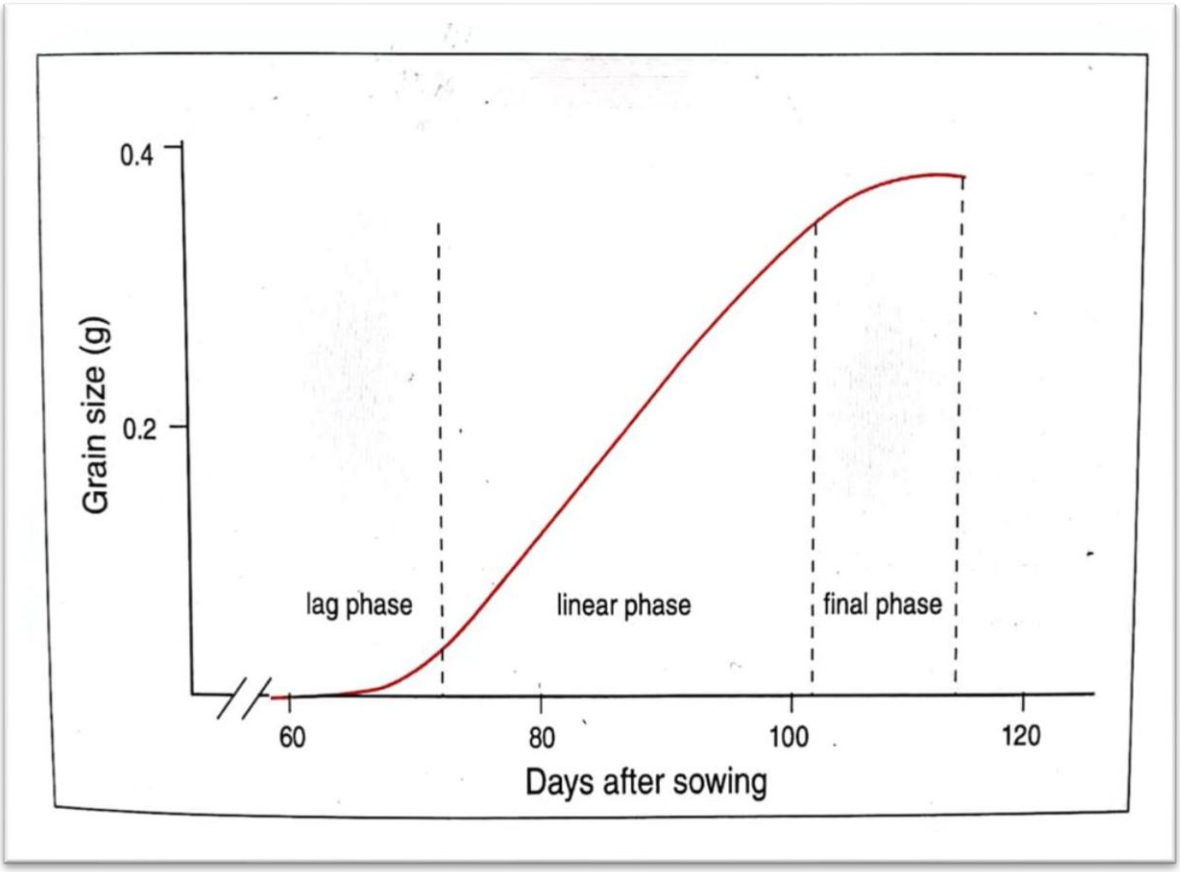

Fig.2. Various phases of kernel development in maize