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Maize: Kernel Composition and Development

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Introduction

Among cereals, maize is a most important crop in the world after wheat and rice. Most of the people used this crop as a staple food, feed for livestock, biofuel and also in industries. In India, maize production is 27.8 million MT with an area of 9.2 million ha having average productivity of 2.9 t/ha. Among all maize growing countries, India ranks 4th in area and 7th in production. It represents 4% of world maize grown area and 2% of total production. According to genetic and archeological evidence, domestication of maize has done from teosinte (*Zea mays ssp. Parviglumis*) around 9000 years ago, in the Central Balsas River Valley in south western Mexico in the states of Guerrero and Michoacán. Maize kernel is a source for most of the energy compounds and in various amounts. Maize plant is monoecious, with male and female inflorescence on different positions along with protan dry (male organs mature before female organs) condition suitable for cross pollination. Male inflorescence(tassel) is situated at terminal position of the plant, however, female(cob) is at axillary position of plant on 4-5 nodes from bottom of the plant. Edible part of maize (kernel) is developed on the cobby an important event of double fertilization(fusion of one male nucleus with egg cell(syngamy), which leads to diploid zygote formation and another male nucleus fuse with the central cell(triple fusion) forms triploid endosperm. Maize kernel composition and kernel development are discussed briefly in this article

Maize kernel composition:

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- Mature maize kernel has embryo (10%), endosperm (85%) and pericarp (5%). Maize endosperm occupies major portion of the kernel (Fig.1). Maize embryo has 18% protein and 30% oil, superior in both quality and quantity.
- Endosperm protein contains starch (90%) and protein (10%). Carbohydrates occupies major portion of maize endosperm. These endosperm cells create two distinct regions: vitreous endospermand starch endosperm.

Maize endosperm has two types of proteins, those are

- Zein proteins and
- Non-zein proteins.

1. **Zein proteins** : These are prolamines (>60%), which are soluble in alcohol. Zein proteins are made up of four different polypeptides protein bodies, those are: Alpha, beta, gamma and delta zein proteins.

- Alpha zein has two sub groups:19KDa and 22KDa. It contributes>60% of total zein proteins in the maize endosperm along with other zein proteins (beta-15KDa , gamma-50,27,16KDa ,delta-10KDa).
  - The zein fraction in normal maize contain higher proportion of leucine(18.7%), phenylalanine(5.2%), isoleucine(3.8), valine(3.6%) and tyrosine(3.5%) and small

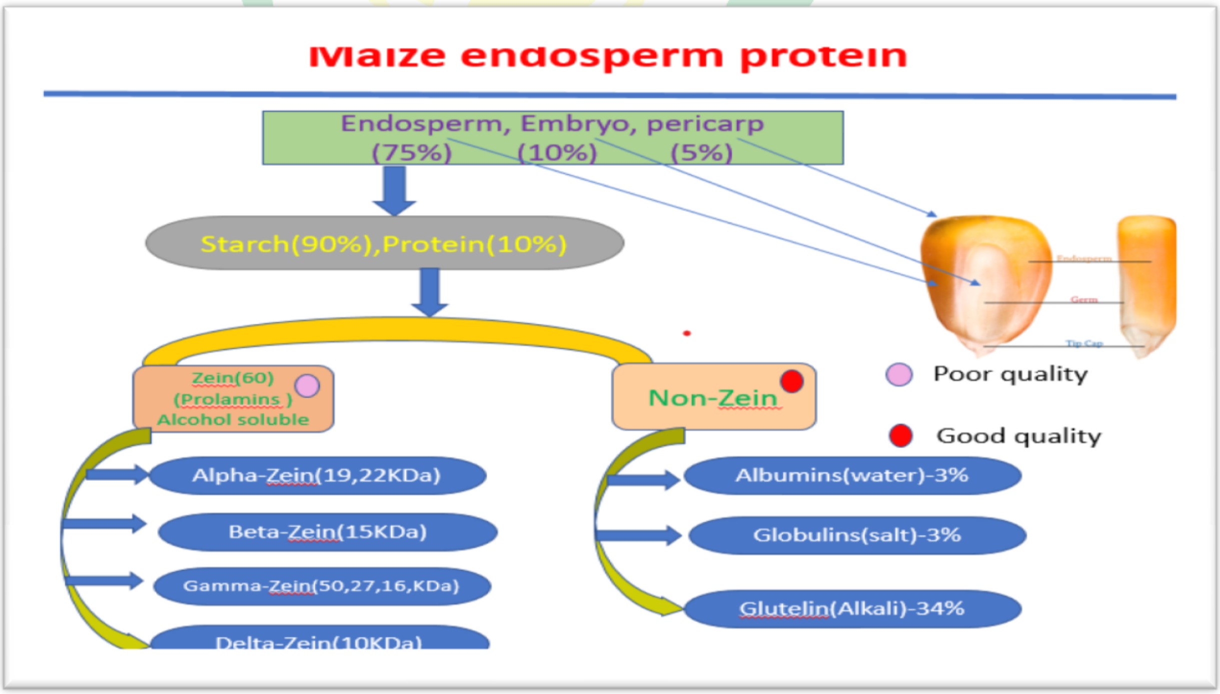

Fig:1- Maize endosperm composition

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- amounts of other essential amino acids such as threonine (3%),histidine and cysteine (1%),methionine (0.9%), and lysine (0.1%). However,tryptophan is devoid from maize alpha –zein portion.

2. **Non-zein proteins** : three types, these are
   - Albumins (3%) – water soluble,
   - Globulins (3%) – salt soluble and
   - Glutens (34%) alkali soluble.

The non-zein fraction is well-balanced and high in tryptophan and lysine. The problems have been mainly dealt by supplementing nutritionally improved grains with lysine and tryptophan by bacterial fermentation. Although, this approach is very expensive.

Kernel development:

Maize is highly cross pollinated crop and often it happens by wind. Pollination happens, when a pollen grain settles down on the silk of the cob, then after pollen tube germinates on the stigma of the silk and it moves to the ovary through pistil. The pollen tube moves along the long silk, however, pollen tube should grow nearly 40 cm to reach the embryo sac. So many pollen grains may deposit on the silk during pollination, although, only single pollen grain fertilizes with the embryo sac. Competition may occur among several

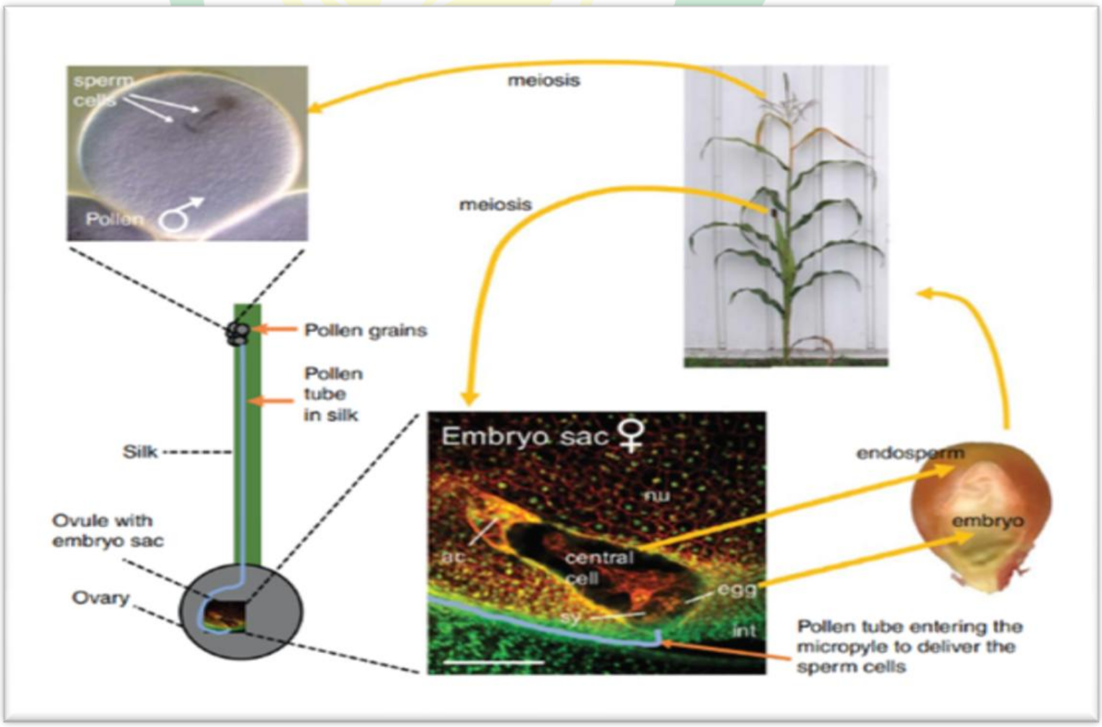

Fig:2- Process of embryo and endosperm development

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pollen grains. However, the one pollen grain, which has effective selection would fertilize. Growth of the pollen tube has been seen with the existing cell wall of the transmitting tract at a rate of 1cm/ hr. Apart from cellular activities, pollen tube tip growth requires additional functions such as vesicle formation, calcium signalling and actin dynamics and it requires some other functions to penetrate female tissue and for interaction with tissue *in vivo*. The biochemical compounds which have been required for this process are secreted by the anther cell wall and these are carried out by the pollen tube coat.

After reaching the pollen tube near to the ovule through the long silk, diploid ovule tissue and female gametophyte would guide the pollen tube towards the micropyle to enter into the embryo sac. The embryo sac consist of three antipodal cells: one at chalazal end, one central cell with two nucleus along with two synergids and one egg cell at micropylar end and it has covered with nucellus and two integuments(both are diploid tissues).Pollen tube enters the embryo sac through micropylar region, reach the synergids and it stops growing, releasing two male gametes into the synergids- one sperm cell fuse with egg cell leads to embryo and another sperm cell mated with central pro nucleus produce endosperm. Antipodal cells persist at the chalazal end after fertilization and it acts as auxin signalling before fertilization and after fertilization these cells acts as signalling centres, and affect endosperm development. Similarly, synergids also persist for at least 5 days after fertilization, but during this time, these cells are larger like embryo and these cells involve in embryo development.

In angiosperms, endosperm is the essential part of seed structure, which involves in embryo development and seedling germination by supplying nutrition and signals. In all cereal crops, endosperm has a major part of the mature grain, having more amounts of storage compounds(proteins, carbohydrates and biofuel).Maize has been called as model system for endosperm development studies, because of its large size and value. Seed development is initiated by a double fertilization during which one of two sperm cells fuses with the egg cell within the female gametophyte (embryo sac) to produce a diploid embryo (1 maternal:1 paternal) and the other fertilizes the central cell to form a triploid endosperm (2 maternal:1 paternal).Although, endosperm nucleus undergo repeated divisions to become a coenocytic cell, it involves in cellularization and produce 7 different cells. These are: embryo-surrounding region (ESR), aleurone layer (AL),basal endosperm transfer layer (BETL), central starchy endosperm (CSE), sub-aleurone (SA), conducting zone (CZ) and

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basal intermediate zone (BIZ). Apart from cell differentiation, two important phases of mitotic cell proliferation has also occurs in the endosperm, first one at 8–12 days after pollination (DAP) in the central region, and a later one that continues until 20–25 DAP in the outer cell layers (AL and SA). Around 8–10 DAP, central portion of the cells in the endosperm slowly transform into endore duplication from mitotic cell cycle and become filled with starch and storage proteins. They eventually undergo maturation and desiccation.

These developmental events correspond to three important physiological periods:

a. A lag period (approximately the first 2 weeks after pollination);
b. A grain-filling period (from approximately 2 weeks after pollination until 6–7 weeks after pollination); and
c. A final period during which grain filling ceases and the kernel matures.

During grain filling stage, kernel dry weight has gained maximum The preceding lag period is a critical formative phase during which kernel sink strength and storage capacity are established through cell division and plastid proliferation. Moreover, the length of the lag period has recently been shown to correlate positively with kernel size.

Conclusion:

Maize has been considered as world staple crop along with wheat and rice, because it have storages of nutrient compounds like carbohydrates, proteins etc. Maize kernel has three important compartments (embryo, endosperm, & pericarp) .Endosperm of maize has two types of proteins like zein and non-zein. These proteins cause hard and soft endosperm. In maize, pollination may occure either wind or any other agent, after reaching the pollen on the silk, the two male gamates with in the pollen should fertilize with egg cell and central cell of female embryo sac and developed into embryo and endosperm respectively. Pollination is a mandatory event to produce maize kernel which involve diverse pathways to develop mature kernel.

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