SEED - THE MASTER KEY

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The head of each successful seed enterprise has a series of individual keys and a master key which is the one key that opens each section of the business. The master key to seed quality is the SEED!

The purpose of this discussion is to focus attention upon the seed; where it develops, how it develops, and the seed's major characteristics after it has developed. Thus, this paper is a review of basic botany as it relates to a seed. Why is it necessary to review such basic information? Because each year we receive a number of questions from seedsmen, the answers to which are directly related to a basic knowledge of seed development, maturation, or the chemical or structural properties of the seed in question.

Seed develop one at a time and not by the bag full! Therefore, a look at the "master key" of the seed industry should be of benefit to both the seedsmen and the farmer when developing answers to questions concerning varietal purity, mechanical damage, deterioration, etc.

Reproduction

There is a point in the life cycle of every plant when the balance of physiological processes shift from the production of leaves, stems and roots to the development of reproductive structures. It is at this point in the life cycle of each plant that seed development really begins, because and for the remainder of the plant's life cycle its entire physiological mechanism is geared toward the development of its reproductive structure, which we call a seed.

This shift takes place long before we can see any flowers, ear shoots, seed heads, etc. Thus, whether producing seed or grain, knowledge of the sequential development of a plant and use of this knowledge to time cultural practices can have a significant influence on yields, and even seed vigor according to a recent study reported by Oregon State researchers. Splitting the applications of fertilizer is based primarily upon the nutrients being available when the plant shifts from vegetative to reproductive growth.

All plants that produce seed have flowers! Some flowers are pretty, others ugly, some small, others large. Flowers occur in almost endless variety of colors, shapes and sizes. There are male flowers, such as in the tassel of corn, and female flowers, such as on the ear of corn. However, most crop plants, all of those we refer to as self-pollinated, have hermaphroditic flowers - that is, each flower has both the male and female reproduction organs within the same flower.

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Figure 1 is a schematic drawing of both a typical legume and grass flower and each is labeled with the technical names of the various parts of the flower. Botanically, all the sepals collectively are called the calyx and all the petals collectively are called the corolla. The calyx and corolla protect the male and female reproductive organs while they are developing but have no direct role in reproduction.

The stamen, which is the male reproductive organ, and the pistil, which is the female reproductive organ, are the structures directly involved in seed formation. A stamen consists of two principal structures, a filament and an anther. The individual pollen grains develop inside the anthers. The filament is a stalk which positions the anther allowing it to most effectively perform its final job of releasing the pollen.

The pistil consists of three basic parts: the stigma, style and ovary. The ovary, which is the structure inside which the seed or seeds are actually formed, may contain one or several hundred ovules.

The stigma may be long and slender, such as a corn silk, feather-like, such as wheat and sorghum, or a knob, as in most legume flowers. Regardless of its appearance, when the stigma is receptive it is covered with a sticky fluid which acts both as an adhesive to hold the pollen grain and a moisture supply which causes pollen grains of the same species to germinate.

The style performs two functions. First, is to place the stigmatic surface in the genetically predetermined position which will increase the probability of the desired pollen landing on the stigma. Second, the style's cellular composition is such that it protects and enhances the growth of the pollen tubes from desirable pollen and discourages pollen tube growth of unrelated species.

The ovary is that part of the flower inside which the seed or seeds develop. The organ which gives rise to the seed is called an ovule. There may be from one to several thousand ovules inside an ovary depending upon the species. Corn, sorghum, lespedeza and zinnias are examples of species whose ovaries contain a single ovule. Soybeans, alfalfa, watermelon and okra have several to many ovules in each ovary. Regardless of the number of ovules, each must be fertilized by the two sperm from an individual pollen grain before a true seed can develop.

A schematic drawing showing cross sections of an ovule inside the ovary wall and a germinated pollen grain are shown in Figure 2. The principle parts of the ovule are the funiculus, integuments, micropyle and the embryo sac. The funiculus, or as some people call it the ovule stalk, connects the ovule to the mother plant functioning similarly to the umbilical cord in animals or rockets. The integuments, there are normally two, serve as delicate fingers to hold and support the embryo sac and later form the seed coat. At the point where the integuments come together a small opening remains allowing entry of the pollen tube. This opening is called the micropyle. Between the inner integuments and
Figure 1. Schematic diagrams of typical dicot and grass flowers.
Figure 2. Cross sections of an ovary containing a mature ovule and a germinated pollen grain.
the embryo sac a layer of cells called the nucellus is formed to aid in the nourishment of the embryo following fertilization.

The embryo sac is the "heart" of the ovule and the location of egg cell which, when fertilized, gives rise to the seed. In addition to the egg cell most mature embryo sacs contain 7 other cells; the antipodal cells are relatively unimportant as are the synergid cells which are located at each side of the egg cell. The two polar nuclei are very important to seed development.

In naturally self-pollinating species both the pistil and stamen in each flower reach maturity at the same time. These organs may or may not mature together in cross-pollinating species. There are other mechanisms which also increase cross-pollination.

The basic mechanics of pollination and fertilization are simple. For each ovule (egg cell and polar nuclei) to be fertilized, a pollen grain of the same species must land on the stigmatic surface. This is pollination. After the pollen grain germinates (Figure 2) the two sperm cells move near the growing point of the pollen tube. When the pollen tube passes through the micropyle and penetrates the embryo sac it ruptures releasing the two sperms into the embryo sac. One sperm fuses with the two polar nuclei and the other with the egg. This process is called double fertilization and is unique to the plant world.

Pollen control is essential to the production of genetically pure seed of all crops.

The union of a sperm and egg cell forms the zygote. It is the zygote that develops into the true seed. The second union, between the second sperm cell and the two polar nuclei, results in the formation of the endosperm. Technically, the endosperm is not part of the embryo, although, in seed such as corn, wheat and sorghum, the endosperm comprises the major portion of what we call the seed. Endosperm is formed following the fertilization process in all seed with its primary role that of providing nourishment to the developing embryo. In the legumes, soybeans, clovers, etc., all of the endosperm is utilized for nourishment of the embryo. In the grasses, endosperm production continues until the fruit and embryo mature.

**Seed Development and Maturation**

Studies of the development and maturation processes of seed of many species have demonstrated that these processes are very similar for all crop species. The major difference in the maturation process of the embryo between any two crops is the time required. This process is complete in 14 to 21 days for most seed of the forage grasses but may require 60 to 70 days for soybeans.

The sequential development of the embryos of corn and soybean are shown in Figure 3. Endosperm development is not shown. Note that initially there is no difference between the two embryos (Figure 3-A).
Figure 3. Four stages of embryo development

Corn (MONOCOT)

A. Soybean (DICOT)

- embryo
- suspensor

B. cotyledon

- embryonic axis
- suspensor

C. cotyledon

- embryonic axis
- suspensor

D. epicotyl (shoot)
- radicle (root)
- cotyledon (stored food)
However, within two or three days after fertilization a visible difference does appear and this difference, cotyledon development, is maintained (Figure 3-B). Figure 3-C indicates the continued increase in size and further development of the embryo. Physiological maturity is attained when the embryo attains its maximum dry weight, although, the moisture content of the seed may still be as high as 60% (Figure 3-D).

The maturation of a seed is a positive growth process which includes the following physical changes: increase in size and weight; accumulation of dry matter; development of the essential structures of the embryonic axis; an increase in viability and vigor and finally, a loss of moisture. The physical relationship between the parts of the flower and a mature seed are summarized in Table 1.

It is important that you know the time requirement between anthesis (flowering) and physiological maturity for each crop with which you work. Seed harvested before reaching physiological maturity, being high in moisture, will shrivel when they dry and probably won't germinate. On the other hand, delaying harvest excessively beyond physiological maturity generally will result in increases in field deterioration, attack by insects and disease organisms, and harvest losses.

For most annual crops, the length of the development and maturation process is shortened somewhat by delaying the date of anthesis until after the optimum date for your area. For example, the same lines of corn were planted on two different dates which resulted in a 21-day difference in date of anthesis. However, seed of the later planting reached physiological maturity only 11 days after those of the first planting. Similarly, a two week delay in soybean anthesis delayed physiological maturity only four days.

Figure 4 is a diagrammatic representation of the steps leading to physiological maturity of a seed followed by the downward steps (deterioration) leading to the death of a seed. A study of this figure should lead you to conclude that a field, ready for harvest, is really a terribly exposed storage place for seed which have already entered the phase of decreasing quality, referred to as deterioration.

Characteristics of Mature Seed

There are several basic facts which are true for the seed of every species. Five of the more important of these basic facts are as follows:

a) a seed must be alive to be of value for reproduction.

b) seed of different species vary in their natural life span.

c) all seed are hygroscopic.

d) moisture content has the most dramatic effect on a seed's longevity and susceptibility to injury.

e) there are slight differences in the chemical and structural
<table>
<thead>
<tr>
<th>FLOWER PART</th>
<th>MATURE STRUCTURE</th>
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<tbody>
<tr>
<td>Ovary</td>
<td>Fruit (sometimes composed of more than one ovule plus additional tissues).</td>
</tr>
<tr>
<td>Ovule</td>
<td>Seed (sometimes coalesces with fruit)</td>
</tr>
<tr>
<td>Egg + Sperm = Zygote</td>
<td>Embryo (embryonic axis and cotyledons)</td>
</tr>
<tr>
<td>2 Polar Nuclei + Sperm Nucleus</td>
<td>Endosperm (usually present in the Gramineae)</td>
</tr>
<tr>
<td>Integuments</td>
<td>Testa (seed coat)</td>
</tr>
<tr>
<td>Nucellus</td>
<td>Persiperm (usually absent or reduced)</td>
</tr>
<tr>
<td>Micropyle</td>
<td>Micropyle</td>
</tr>
<tr>
<td>Funiculus</td>
<td>Hilum (scar left by breaking of the funiculus)</td>
</tr>
</tbody>
</table>

Table 1. Comparison of flower parts to mature plant and seed structures.
Figure 4. Steps in the development and death of a seed:

- **Fertilization**
  - **Increase of dry weight**
  - **Structural development**
  - **Increase of viability**
- **Moisture**
  - **Loss**
  - **Respiration**
  - **High relative humidity and temperature**
  - **Mechanical injury**
- **Diseases and insects**
- **Death (grain)**

- **Physiologically mature seed**

- **12 to 60 days**
- **Few days to many years**
make-up of the seed of different varieties and great differences among seed of different species.

Both the chemical composition and relationships of the essential structures of seed of different species have significant effects upon the equilibrium moisture content, the rate of deterioration and their susceptibility to mechanical injury.

The major chemical substances which exist in each seed can be divided into three categories: oils or fats, starches or carbohydrates and proteins. Most people think of the soybean as a high oil seed and corn as a high starch seed. However, in reality many of the high oil seed may contain more protein or starch than oil, therefore, this classification is not absolute. For example, in Table 2 the chemical composition of soybeans, a "high oil" seed, cowpeas, a "high protein" seed, and corn, a "high starch" seed, are given.

Table 2: Chemical Composition of Three Seed Kinds.

<table>
<thead>
<tr>
<th>Seed Kind</th>
<th>Oils (%)</th>
<th>Protein (%)</th>
<th>Starch (%)</th>
<th>Moisture (%) (5 C-50%RH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>20.5</td>
<td>37.9</td>
<td>34.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Cowpea</td>
<td>1.0</td>
<td>27.0</td>
<td>61.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Corn</td>
<td>4.3</td>
<td>8.0</td>
<td>77.3</td>
<td>11.5</td>
</tr>
</tbody>
</table>

First, consider the influence of chemical composition on equilibrium moisture content of seed. Remember, all seed are hygroscopic. Therefore, all seed will either absorb or lose moisture with the surrounding atmosphere until an equilibrium is reached between the moisture content of the seed and the relative humidity of the surrounding atmosphere. The amount of moisture in a seed at equilibrium is directly related to its chemical composition.

At most relative humidities, the equilibrium moisture content of a "high starch" seed, such as corn, will be higher than that of a high oil seed, such as soybean as indicated in the right hand column of Table 2. This is true because oil and fats don't mix with water.

When you measure the moisture content of corn or soybeans you weigh out 100 grams. But look at the difference in the oil content of these crops and you can readily see that about 96% of the corn material can absorb moisture but only 80% of the soybean material will absorb moisture. Thus, the total amount of moisture in corn is higher than that of soybeans.

The thought that equilibrium seed moisture is inversely related to
oil content, is not always true as can be determined by examining the data given in Table 3. At 93% relative humidity the moisture equili-
rium of both "high oil" soybeans and "high protein" cowpeas is higher than that of corn. Why this change in moisture absorbed? It is related to the response of the proteins to very high relative humidities. Remember, soybeans and cowpeas both have more than 25% protein but corn is only 8% protein (Table 2.)

Table 3: Effects of Seed Chemistry on Equilibrium Moisture Content.

<table>
<thead>
<tr>
<th>Seed Kind</th>
<th>Relative Humidity (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Soybean</td>
<td>6.2</td>
</tr>
<tr>
<td>Cowpea</td>
<td>7.5</td>
</tr>
<tr>
<td>Corn</td>
<td>9.1</td>
</tr>
</tbody>
</table>

The effects of seed chemistry on moisture content can be summarized as follows:

a) Equilibrium seed moisture is inversely related to oil content at relative humidities below 75%.

b) Protein content of a seed has little influence on equilibrium moisture content when the RH is below 75%.

c) Starch retains the same relative influence on seed moisture at all relative humidities.

Speed of deterioration is another factor greatly influenced by the chemical composition of the seed as indicated by the results presented in Table 4. Generally, as the percentage oil in a seed increases the speed of deterioration increases. Peanuts are higher in oil content than soybeans. On the other hand, the chemical analysis of a soybean and a cotton seed is similar, however, high quality cotton seed store well under ambient conditions in Mississippi for about 24 months, while soybeans of equal, initial quality will maintain satisfactory germination for only 9-12 months.

Chemical composition also influences the susceptibility of seed to mechanical injury. Starches which occur in seed are classified as either soft or hard. In dent corn we find both types. The soft starch is easily penetrated, but rarely breaks. The hard starch, on the other hand, resists mechanical pressure up to a point and then fractures. In rice, another high starch seed, the natural stress created by rapid drying of the starchy endosperm while the seed are still in the field is often sufficient to cause fractures across the endosperm. This is called "sun-checking." Fortunately, this fracturing does not materially affect the viability of the rice seed, but is generally fatal to corn, wheat, sorghum, soybeans and other seed.
Table 4. Germination of Seed Lots Stored Under Mississippi Conditions

<table>
<thead>
<tr>
<th>Seed Kind</th>
<th>Storage Periods (Mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>High Oil</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>96</td>
</tr>
<tr>
<td>Peanut (Shelled)</td>
<td>96</td>
</tr>
<tr>
<td>High Protein</td>
<td></td>
</tr>
<tr>
<td>Snap Bean</td>
<td>98</td>
</tr>
<tr>
<td>High Starch</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>98</td>
</tr>
<tr>
<td>Wheat</td>
<td>98</td>
</tr>
</tbody>
</table>

Some high protein seed, such as lima and snap beans, become extremely fragile at moisture contents necessary for safe storage. This fragility is directly related to the chemical composition and cell structure of the cotyledons of these seed.

Many seed have one or more structural weaknesses which are an unending source of problems to seedsmen. The seed coat of many seeds, when undamaged, is a better protectant than most seed treatments that we add. In the largest true seed, the coconut, the seed-coat is hard and offers excellent protection to the delicate embryo, but most seed are not so well protected. Rather, they are covered by a thin shell like an egg which, in our mechanical age, is often broken by dropping a few feet or a slightly more severe shock. We are fortunate that many seed are either so small, light, or protected by additional coverings they escape man's attempts to kill them.

Natural differences in physical structure among seed of different species affects their susceptibility to injury, moisture absorption rate, and longevity. Seed can be classified into five categories based on their structural characteristics. These categories are: (a) "weight protected seeds", (b) "structure protected seed", (c) "loose filled seed", (d) "naked fruit", and (e) "naked seed".

Weight protected seeds -- Typical weight protected seed are ryegrass, fescue, orchard grass, tomato, etc. Protection arises from the fact that the seed, as it is normally encountered, is so light that it escapes damage. When dropped, the seed do not gain sufficient velocity to be injured or when hit, the seed offers very little resistance to the object which strikes it. Seed of this category are additionally protected by the natural accessory parts that remain attached to the seed.

There is a tendency for some of the seed in this group to change
several percentage points in moisture with no appreciable change in physical dimension, thus, an increase in weight per bushel may be observed with small increases in moisture content. Most seed of this category are quite susceptible to cutting and crushing because the seed coverings, usually the lemma and palea, are not mechanically strong.

Structure protected seed -- As the name implies the seed in this classification are protected by either their accessory structures or seed coats. Red clover, alfalfa, vetch, etc., are representative of this group. Even though the radicle is rather exposed due to the seed's structure the seed covering is relatively thick and hard and offers excellent protection to the embryo. However, not all small seeded legumes are included in this category.

Rice and sudangrass are also representative of this group. Although, structurally, the "hulled" seed are essentially the same as grain sorghum, a naked "fruit", the tough, durable lemma and palea give excellent protection against mechanical injury.

Loose filled seeds -- Seed of this category are those which are characterized by a comparatively thick, tough, rigid seed coat or covering such as that found in cotton, sunflower, castorbean, etc. The seed coat acts as an excellent protectant for the fragile embryo under normal conditions. It has been proven conclusively that most of the seed quality problems associated with seed of this category occur after this protective cover is broken. Nevertheless, the protective covering is crushed, cut and often removed by mechanical equipment and each year seedsmen and farmers wonder why they can't find high quality seed to plant.

Another characteristic of loose filled seed is that as the seed mature, the seed coat will develop to a genetically predetermined size, but the embryo may not completely fill the space provided. This differential development leaves an air space inside the seed coat. As a result, when we measure the seed dimensionally, they are the same size, but often differ in specific gravity because of different amounts of air space. This characteristic permits effective separation with a gravity table.

Naked fruits -- Botanically, what we call "seed" of the grass family are really fruits which have a seed imbedded in them, thus, the classification "naked fruits". In this category, to which all cereal grains belong, some protection is afforded the embryo by the endosperm which encircles it on three sides. Thus, simply by chance three out of four injuries are likely to occur to the less vital endosperm and, although weakened, the seed will produce a plant. However, this protection is somewhat deceiving since a light shock will penetrate the very thin membrane covering the exposed portion of the embryo.

Naked seeds -- The last category of seed are classified as "naked" seed. As the name implies, they have very little natural protection and relatively careful handling will often damage the embryonic axis or the two cotyledons. Seed typical of this category are soybeans, cowpeas,
shelled peanuts, and beans.

Most naked seed belong to the legume family and are formed inside a pod. When these seed are harvested, this protective pod is removed exposing the seed to all types of deteriorative effects. The thin seed coat offers little protection against moisture migration, except when it contains waxy substances, and offers little structural protection to the embryo. Additionally, the structural weaknesses, thin seed coat, exposed embryo, etc., often exist in combination with other undesirable relationships attributable to the chemical composition previously discussed.

The factors discussed: reproduction, development and maturation, and the physical and chemical characteristics of the mature seed are the factors which control the true quality of this master key, the seed, which in turn opens the door to genetic stability, the continuing cycle of life, and for many people profit or loss.