Row Crops Newsletter

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MISSISSIPPI STATE UNIVERSITY EXTENSION SERVICE

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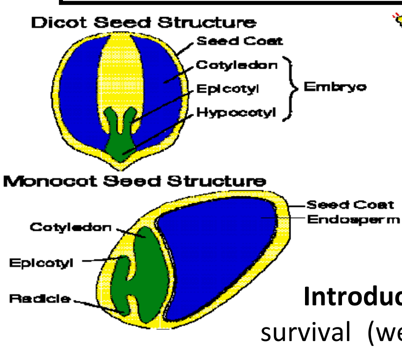

Seed Germination

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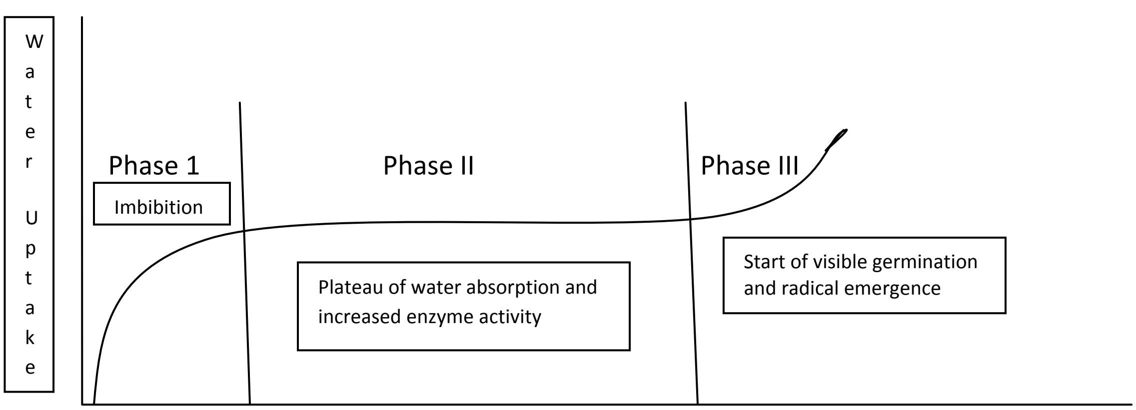
Introduction: The seed is a living plant within a seed coat allowing species survival (weeks to hundreds of years), movement to new geographies (cocklebur, dandelion, *Desmodium sp*.) and genetic recombination (resistance in Palmer and sand-hill amaranth). Seed is comprised of everything necessary to develop a mature plant when provided the correct environmental conditions. Within the seed coat is an embryonic axis, comprised of a radical, shoot and cotyledons. It also has stored foods that sustain the embryo until it becomes able to absorb sunlight and become autotrophic (self sustaining). Seed production begins with pollination and fertilization allowing the embryo to go from a fully hydrated state to a dry state (10-13% moisture). The seed is alive with respiration occurring at low rate. Upon rehydration (imbibition), germination begins upon water absorption and triggers cell division, cell elongation and cell differentiation resulting in radical emergence followed by seedling growth. Plant life begins with the seed that dictates success or failure.

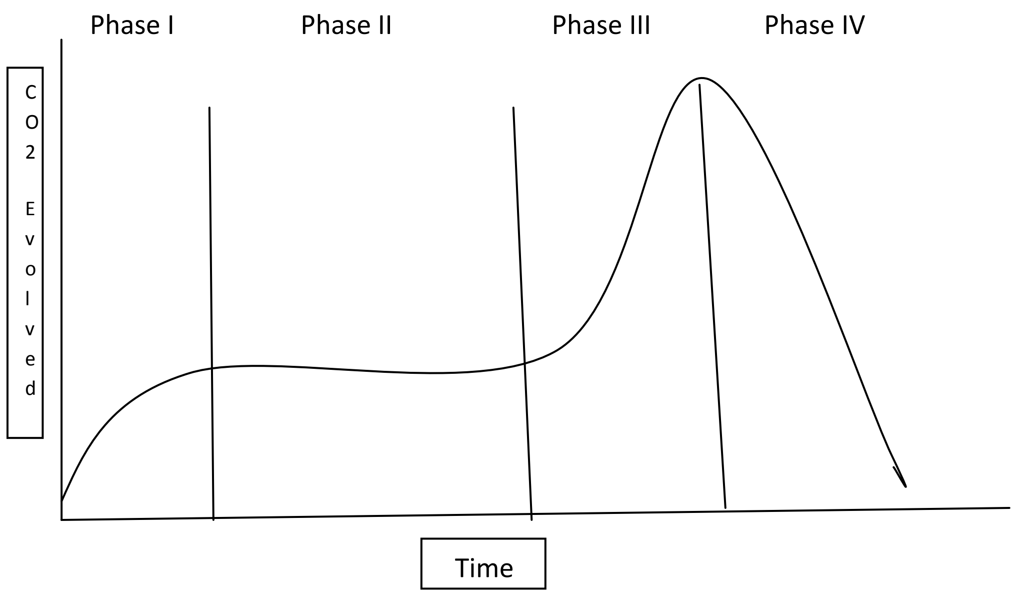
Seed Germination is the sum of events beginning with hydration and culminating with root emergence. There are several stages involved in germination. These include 1) imbibition of water, 2) activation of enzyme systems, 3) metabolism of storage products and their transport and 5) the emergence of the radical and growth of the seedling.
Stage 1- Imbibition of water: There are two events occurring in water imbibition and they include the water uptake and increase in respiration. The seed is very dry and has a strong propensity for water. Remember, water flows from a region of high concentration to one of low concentration or from wet to dry. Water absorption has three phases. In **phase I**, there is rapid water absorption independent of metabolic activity but dependent on soil texture, degree of packing, proximity of seed to soil and seed to soil contact. **Phase II** shows little water absorption since the seed is saturated. However, there is an increase in enzyme activation and synthesis that will be used in Phase III. **Phase III** is associated with another water uptake where radical emergence and elongation occurs. This results in cell elongation without cell division. In this stage enzymes activated in Phase II break down storage materials (fats, proteins, carbohydrates and phosphorous containing compounds) and transfer them to growing points.

Stage I of seed germination-Imbibition



Stage 2 – Increased Respiration: Respiration follows four phases that tracks closely to water absorption. Respiration involves the uptake of oxygen and the conversion to carbon dioxide and in the process the generation of energy. **Phase I** of respiration involves the activation and hydration of existing enzymes. **Phase II** involves a plateau in oxygen uptake caused by the seed coat restricting gas exchange. **Phase III** shows an increase in oxygen resulting from the formation of new enzymes in the dividing cells that leads to the resurgence of respiration. **Phase IV** shows a decline in respiration as the seedling emerges and begins to photosynthesize.

Stage 1 of seed germination-Respiration



Stage 2 - Activation of enzyme systems: There is great evidence show-casing the activation of newly formed enzyme systems that is evidenced by the following; 1) Increased enzyme activity prior to germination. 2) Use of protein synthesis inhibitors which inhibits germination. 3) Incorporation of radioactive precursors into proteins to track the enzyme systems. 4) Use of immunological and molecular techniques.

Stage 3-Formation of enzyme systems and metabolism of stored compounds: Metabolism or stored products and their transport can occur via the activation of pre-existing enzymes or their pre-cursors, activation of pre-existing but inactive enzymes and the synthesis of new enzymes from pre-existing or newly produced mRNA. There are many enzymes involved in this process that include; lipases (break down lipids to fatty acids and glycerol that produce membranes and energy), proteinases (break down proteins to smaller compounds) and phosphatases (responsible for nucleic acid and protein synthesis).

Stage 4-Radical emergence and seedling growth: This is associated with the second water uptake leading to radical emergence and seedling autotropism (self dependent). Here cell division (increase of cell number) in the root and shoot and cell expansion begins. Also the seedling is divided into a hypocotyl (stem region below the cotyledons) and epicotyl (stem region above the cotyledons) and respiration drops significantly since the seedling begins responding to sunlight.

Hormones in seed germination: During the embryo development, endogenous plant hormones (Gibberellins (GA), Auxins (IAA) and Cytokinins (CK)) increase in the embryo while the developing embryo is heterotrophic (dependant on the mother tissue for support). In later stages of embryo development, Abscisic (Acid ABA) levels increase that will maintain seed dormancy. There is a great interaction between GA, CK and ABA during seed germination. Seed germination cannot occur without the presence and activation of GA. However, if ABA is present at high levels, germination will not occur since ABA blocks GA. But if CK is in an active form, it suppresses inhibition of ABA on GA and germination can occur.

Relationship	GA	CK	ABA	Response
1	+	+	-	Germination
2	+	-	-	Germination
3	+	-	+	Dormancy
4	-	-	-	Dormancy
5	-	-	+	Dormancy
6	-	+	-	Dormancy
7	-	+	+	Dormancy
8	+	+	-	Germination

Hormones work in germination by a line of communication that exists within the seed. Upon imbibition, a signal is sent from the living starch containing tissues beneath the seed coat (aleurone layer) to the embryo to send it GA to activate an enzyme called alpha amylase (most enzymes end in *ase*) responsible for breaking down starch. The GA moves from the embryo to the aleurone layer unless ABA is present which blocks the movement of GA. However, if CK is present it blocks ABA and allows GA to move forward for storage material degradation and germination. In many cases, especially in native or weed seed, the movement of water is necessary to flush out the ABA and other inhibiting compounds. In some cases an after-ripening or stratification period is necessary. **After-ripening** is a process needed when seed are harvested prematurely as in seed harvested in winter nurseries in other countries and shipped to the United States for planting. Seed harvested prematurely will provide slow or uneven germination even when exposed to ideal conditions. After-ripening is a process requiring warm and dry storage ranging from weeks up to 8 to 12 months at 20-40° C to allow further water loss. In this process GA levels increase and ABA declines. It has been a well documented in horticultural (tomato cultivar Moneymaker) and agronomic crops. **Cold stratification** is a process where the seed is exposed to periods of temperatures of 2-4° C to break dormancy. In this state the seed must be in an imbibed state. The time frame ranges from days to several months but the longer the chilling period the more complete the germination. Some species require alternating temperatures while others will require partial drying. Whatever the reason, it allows increased GA and reduction in ABA. Cold stratification is very important to weed species and can explain why some weed species germinate differently. This is also a survival mechanism, preventing premature germination prior to damaging cold weather.

Hormones are also important in fruit set via the seed. There is a period of no fruit growth following pollination unless fertilization occurs. The developing fruit will bear the seed and the seed can be a strong sink for hormones. IAA, produced in the developing seed, is very important in fruit set. It moves to developing fruit tissues signaling the plant that there is a viable fruit and to not abscise. If fertilization occurs the IAA level will increase but if little or no fertilization occurs the IAA will be low at these sites. This is why many of our agronomic and horticultural crops will shed fruit. Fruiting plants produce more flowers than be can realistically carried and the plant has a pre-determined number of fruit it can carry. Via non-pollination or natural fruit shed (June drop in apples, August drop in pecans, fruit shed of cotton) the plant will protect itself directly while improving fruit quality and size. Remember, yield is linked to fruit number and size. If the plant carries a heavy crop , it can promote biennial bearing as seen with pecans since the current year crop deprives next year's buds from food reserves. Heavy fruit production can also affect fruit size and quality (why peaches, apples and others are thinned) especially under non-irrigated and/or low fertility situations. Other hormones linked to fruit set include GA and CK.

Factors affecting seed germination: There are several environmental factors affecting seed germination. The first and definitely the most important is water followed by temperature, gases (Oxygen) and light.

Water and seed germination: One consequence of water is associated with high salt concentrations that can prevent water from flowing into the. Water impacts can be due to low soil water concentration which can allow partial seed swelling but not enough for full germination and not enough water to remove germination inhibitors like ABA. The last consequence of water is with too much water where substances are produced inhibiting oxygen uptake and there is an increase in the carbon dioxide concentration around the seed reducing respiration and enzyme synthesis.

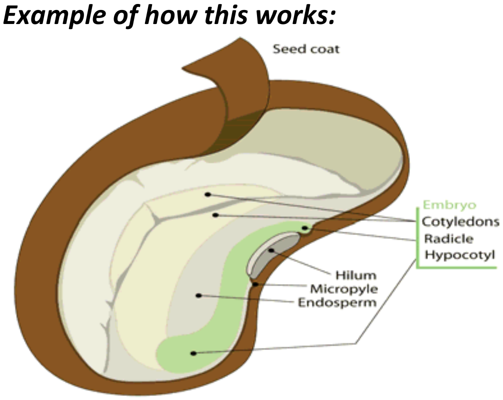
Temperature and seed germination: All seed have a minimum, optimum and maximum temperature. Seed germination is slow in the minimum range, speeds toward the optimum and reduces again at the upper maximum level.

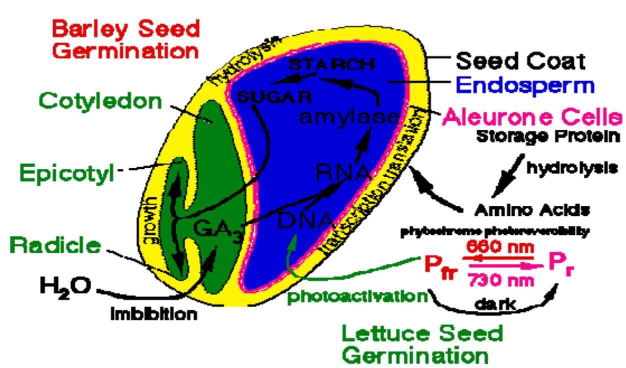
At the minimum range seed is pre-disposed to imbibitional chilling injury, seed rot and seedling diseases. In row crops and many vegetable crops, this is where a good fungicide seed treatment is necessary. Temperature regulates the percent germination, rate of germination and seedling growth. There are four temperature seed groups: **Cool temperature tolerant seed** germinate at temperatures of 4°C but will germinate at higher temperatures. Examples include broccoli, carrots and cabbage. **Cool temperature requiring seed** will not germinate at temperatures above 25°C and examples are coleus and delphinium. **Warm temperature requiring seed** will not germinated below 20°C and are damaged at 10-15°C via imbibitional chilling injury. Examples of these include cotton, soybean, corn and warm season vegetable crops. **Alternating temperature requiring seed** require a period of alternating temperatures either diurnal or seasonal. In the diurnal temperatures there must be a 10-15° C difference between the night and day. Seasonal alternating temperature is a defense mechanism protecting seed from germinating prematurely. This is very common in wild flowers and weed species.

Aeration: Gas exchange is very important for rapid and uniform germination. Oxygen is required for respiration during germination and carbon dioxide is a by-product of respiration but if allowed to build around the seed due to heavily packed or saturated soils can prevent seed germination.

Light: Some vegetable and weed seed are light requiring (photoblastic). This involves a pigment (phytochrome (Phy)) in the seed coat membrane. For seed to respond to light it must be imbibed. Light affecting seed germination is Red (R) and Far Red (FR) light. Phy R absorbs in the 660 nm range while Phy FR absorbs in the 730 nm light range. The two Phy include Phy R and Phy FR. Phy R and FR represents the same molecule but different rotations in the terminus ends of the molecule relative to light quality and quantity. Red light is absorbed by Phy R and signal passed to Phy FR which allows germination. FR light is absorbed by Phy FR and activates Phy R which disallows germination. FR and green light is greater under a forest or row-crop canopy than Red light and accounts for limited germination beneath the canopy. However, if a canopy break occurs more Red light penetrates enhancing germination of photoblastic species. This can be further linked to the presence of Phy A and B which are actually two different Phy that allow seed to recognize very low light levels and low light levels respectively. Phy A accumulates in the dark increasing light sensitivity. This is why soil tilled during the day allows germination while night tillage does not. Phy A is why there is limited germination under a canopy but not to a significant level. However, if a break occurs in the canopy there is a higher level of Red light that excites Phy B and facilitates greater germination. This process also allows the seed to recognize the proximity of the seed to the soil surface which becomes important since most weed seeds are relatively small and have a limited supply of stored energy. If they germinate at a deeper depth, they will run out of energy before reaching the soil surface and perish. It should be stated that some germination will occur thanks to Phy A at very low light levels but the majority occurs thanks to Phy B under low light levels. Also, there is more FR light in the fall of the year reducing the germination of photoblastic seed. The bottom line is that Phy FR is the active form of Phy and will allow germination while Phy R disallows germination. The interesting thing about seed and light is its ability to remember what light spectrum it was exposed to. Lettuce seed requires Red light for germination and if exposed to Red light while imbibed can be dried and stored for up to one year without having to be exposed to Red light again. However, if exposed to FR light it will not germinate. In germination, Red light stimulates GA and CK activity. This is also why we see weed breaks at the end of season following the crop dropping its leaves.

Example of how this works:





The hormone signal in barley (Gibberellic acid) activates DNA in the aleurone cells. The transcription and translation of a gene for amylase occurs in the aleurone cells. This enzyme is shipped to cell organelles, packaged into vesicles and exported through the cell membrane. The amylase is dumped into the endosperm area where it breaks down starch to sugar and is transported to the embryo to fuel respiration allowing root emerge. A similar mechanism occurs in lettuce (no aleurone), but the activating chemical is Phy. How lettuce seed responds depends on how much Phy R and Phy FR exists in the cells. Typical lettuce seed batches germinate at 30-60% if placed in darkness because at least this many seeds have enough Phy FR to stimulate germination. If lettuce seed, is placed in red light all the Phy R changes to Phy FR allowing 85-95% germination. On the other hand, lettuce seeds are placed in far-red light, Phy FR changes to Phy R and preventing germination.

An example from this area last growing season is the large population of spiny amaranth. Why this happened can be answered by using what was discussed. We had one of the coldest winters we have had in years accounting for adequate stratification. This was followed by a very wet spring and early summer and we had good red light. These weeds were worst in pastures and where we had skips in our crops, around borders and after the crop began to dry down.

Seed Dormancy: This is a very interesting subject that allows the seed to perpetuate itself for long periods of time in a quiescent state. Dormancy is a term used to describe a temporary suppression of visible growth of any plant structure containing a meristem or site of growth. A seed is said to be dormant when it is subjected to favorable environmental conditions and will not germinate. Dormancy can exist in two forms; **quiescent** (results from exogenous factors like temperature or water) and **rest** (results from endogenous factors that prevent germination even when exposed to favorable environmental conditions). Here are three terms very important in understanding dormancy; **ectodormancy** (dormancy due to external factors), **paradormancy** (dormancy due to physical and biochemical internal factors originating external to the plant structure being affected. Within is seed but outside the structure being affected), and **endodormancy** (dormancy due to internal physiological factors despite the embryo being presented favorable environmental conditions). There are four levels of dormancy; primary or innate, secondary or induced, relative and suppression of precocious germination. **Primary dormancy** is an acquired type of dormancy during the natural maturation while the seed is still attached to the mother plant and therefore, is dormant when shed by the mother plant. Types of primary dormancy include; **physical** (regulated by the seed coat and is a paradormancy), **mechanical** (due to a hard seed coat and is a paradormancy), **chemical** (due to inhibitors like ABA and is a paradormancy), **morphological** (due to an immature embryo and is endodormancy and paradormancy), **physiological** (thermodormancy and photodormancy and must be overcome by alternating chilling and/or light. It is a paradormancy). Physical and mechanical dormancies are a form of **Seed Coat Dormancy** which results from the seed coat preventing water or oxygen from entering the seed or the radical from emerging from the seed coat. Examples are the prevention of gas flow into the lower seed of the cocklebur, a plugged micropylle preventing water entry, a waxy seed coat preventing water entry or lignified seed coat that prevents radical emergence. **Secondary dormancy** is a safety mechanism that is implemented from the seed being exposed to adverse conditions once it falls from the plant and functions for imbibed seed. This dormancy can be promoted by high salt conditions, high or low water, high or low temperature, prolonged exposure to darkness, prolonged exposure to Far Red light and prolonged exposure to white light. **Relative dormancy** is where the seed falls from the plant in a dormant state but exposure to brief light or high temperatures breaks the dormancy. **Suppression of precocious germination** is caused by ABA that prevents premature germination and is unlike seed that possess vivipary (where seed gives rise to living young while being on the plant). These seed never dry down and produce a radical while on the plant so when it falls from the plant can form a mature plant. These are called **unorthodox** or **recalcitrant seed** and have a 50-60% moisture level at shed. An example is Mango. **Orthodox seed** dry down normally, enter a quiescent period and is typical of row crop and horticultural seed. Other dormancy types include **embryo dormancy** (intrinsic dormancy inherited from the mother plant disallowing germination despite exposure to favorable environmental conditions) and **double dormancy** (where two or more dormancies exist simultaneously and must be broken sequentially).

Man, there is a great deal going on inside that tiny bundle of joy (crops) or pain in the derriere (weeds). I hope you see that whether we are dealing with row crops, horticulture crops or weeds, seed germination and plant growth is basically the same with some species differences.

For more information feel free to call me at 601-813-7166.