

Seed Germination for Transplants

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ADDITIONAL INDEX WORDS. priming, vigor, stand establishment, dormancy, temperature

SUMMARY. Seed germination is a critical step to achieve economic success in a transplant operation. Total germination of a seed lot dictates total plant sales by the producer, while uniformity of germination dictates the quality of the transplant crop. Using high vigor seed will help to achieve uniform stands, as well as maximize stands, in the transplant house or field. In order to maintain the highest seed quality, transplant producers should store unused seeds at recommended temperature and relative humidity for the crop species. Methods to promote uniformity and optimum stands under a wide range of conditions include the use of seed priming, film coating with fungicides, and pelleting for ease of planting

With the advent of precision seeding and mechanical harvesting, growers and seedsmen are more demanding of good seed germination and seedling growth. Optimal plant stands are needed by the grower for highest economic return. Poor quality seed will eventually lead to sales losses by the transplant producer. Seed storage conditions can adversely affect seed longevity, germination and seedling vigor. Storage at high temperature and high relative humidity can rapidly reduce germination and seedling vigor.

Germination and seedling growth

Germination, in the strict sense, is the resumption of active growth of the embryo, usually after a state of rest (Bewley and Black, 1994). This eventually results in the breaking of the seed coat and the emergence of a young plant. The seed physiologist may measure radicle germination after measuring biochemical change(s) in the seed or at radicle emergence. The seed technologist measures germination only after a normal plant is observed, i.e. root and shoot which are normal in appearance. On the other hand, a farmer only counts seedlings which have emerged from the soil as germinated. This may or may not be the point where a transplant producer

counts a seed as germinated. Generally, only usable seedlings are factored-in and counted as germinated seedlings.

Germination of crop seeds follows a specific sequence of events. They include: imbibition of water, enzyme activation, initiation of embryo growth, rupture of the seed coat, and emergence of the seedling (Kigel and Galili, 1995).

Imbibition, or the movement of water into the seed, first occurs as a physical movement through natural openings in the seed coat. Water generally moves throughout all seed tissues and is termed the passive phase (Bewley and Black, 1994).

The rate and total volume of water movement is dependent on the seed coat, seed composition, and to a lesser extent, temperature. Seeds such as soybean [*Glycine max* (L.)], which contain protein as the major storage component, will reach a larger final volume than seeds that contain a large amount of starch, such as corn [*Zea mays* (L.)]. After an initial rush of water movement into the seed there is a lag phase, where respiration starts and the imbibition rate slows down (Taylorson, 1989). After the lag phase water movement begins again due to growth, usually of the radicle through the seed coat. This phase is regulated by both the physical properties of the seed and the metabolic processes going

on in the seed. This is more related to an active phase of water uptake because it represents active seedling growth.

Water causes the cells in the seed to become turgid, the entire seed enlarges in volume, and the seed coat becomes more permeable to gases such as oxygen and carbon dioxide (Kigel and Galili, 1995). As the seed swells, the seed coat may rupture, facilitating water and gas movement. Generally, dry seed moisture content is from 5% to 8% on a fresh weight basis. Imbibitional seed moisture content will rise rapidly to over 60% to 80%. The embryonic axis will have to attain a moisture content >90% for radicle development, whereas, other portions of the seed may still be <50% moisture after 12 h of imbibition. This is especially true in starchy seeds.

As previously mentioned, there are three stages or phases of water uptake. Phase I may be the most rapid, usually lasting from 1 to 8 h (Bewley and Black, 1994). Lettuce (*Lactuca sativa* L.) seeds will generally complete Phase I imbibition in 1 to 2 h. So long as the seed coat does not interfere with water uptake, imbibition in Phase I is similar in both dead and living seeds as well as dormant and nondormant seeds. This is why it is termed passive. Phase II or the lag phase can last for several hours to several days, and longer if the seeds are dormant. Phase II concludes

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generally when the radicle protrudes through the seed coat. It is during Phase II that the major metabolic events take place which lead to the completion of germination. Dormant seeds remain in Phase II until dormancy is released. Phase II metabolic events include membrane reorganization, enzyme activation, protein synthesis, storage material breakdown, RNA synthesis, and sugar metabolism for energy derivation. Many times dormant seeds will have elevated levels of respiratory activity during Phase II, as well as certain types of synthetic processes taking place. However, depending on the type of dormancy, these seeds generally do not begin cell division. Most transplant crops do not go into a dormancy phase, although some flower seed crops may [e.g., geranium (*Pelargonium* sp.)], which possesses a hard seed coat that can restrict water uptake). The final phase, Phase III, is also a period of rapid water uptake. This is generally related to cell division and cell expansion, radicle protrusion, and eventually hypocotyl elongation and protrusion from the seed coat. This marks the end of germination and the beginning of seedling growth.

Factors affecting germination

The length of time for germination and its various phases is dependent on many factors. In the transplant house, it would be dependent upon moisture availability, media composition, aeration, temperature, and sometimes light when needed. Under conditions of high or low temperature, the processes of Phase II would be much delayed. Thus, seeds which have been planted in moist media should be maintained close to their optimum germination temperature. This temperature will provide the most rapid and generally the most uniform emergence of seedlings in the transplant house.

Transplant growers should also understand that various seeds respond differently to the above-mentioned environmental conditions, and that the quality and vigor of the seed itself will predispose the seedling to its optimal growth rate (McDonald and Nelson, 1986). Such things as the size of the seed, the composition of the seed, the

size of the embryo, and seed coat permeability (in regards to water and gas exchange) all influence the rate of imbibition in Phase I and the length of time that the seed remains in Phase II. Generally, Phase I is more affected by water availability and inherit seed characteristics than other outside environmental conditions.

MOISTURE. For transplant producers, it is generally easier to maintain adequate moisture levels in the transplant tray or in the transplant field than it is to control temperature. Transplant producers are encouraged to wet their seeds immediately following planting. This offsets problems of maintaining seeds in trays or in field conditions wherein soil moisture conditions are variable, and thus, initiating germination in the seed population at different times. If seeds are not wetted immediately following planting, certain seeds in a population may be predisposed to moisture levels which will initiate the early stages of germination. Thus, when the entire population is then wetted, it can lead to variable stand establishment.

Some flower seeds need wet conditions (i.e., continuous field capacity). These seeds include impatiens [*Impatiens walleriana* (Hooker)], begonia (*Begonia* sp.), pansy [*Viola tricolor* (L.)], ranunculus (*Ranunculus* sp.), and cyclamen [*Cyclamen africanum* (Boisser & Reuter)] (Styer and Koranski, 1997). Most vegetable seeds germinate best at field capacity. Some seeds germinate better under dry conditions. These conditions really mean high humidity, but not excessive moisture. These seeds include seedless watermelon [*Citrullus lanatus* (Thunberg) Matsumura & Nakai], aster [*Callistephus chinensis* (L.) Ness], zinnia [*Zinnia angustifolia* (Kunth)], verbena [*Verbena hybrida* (Voss)], and delphinium [*Delphinium elatum* (L.)]. Excessive moisture can lead to anaerobic conditions, especially when media and soil types are quite dense. In a plant house situation, this condition is further exacerbated by stacking flats in the germination room. Conditions of too much moisture can reduce germination and make the seeds more sensitive to high temperatures. Thus, moisture, temperature, and gas ex-

change are intimately interrelated with one another.

TEMPERATURE. Temperature is extremely hard to control, especially in field plantings. In greenhouse transplant culture, germination may be best controlled by placing the transplant trays in a controlled temperature room so that the optimum temperature may be maintained. The period of time in the germination room should last no longer than to the initiation of radicle protrusion.

A limiting step in germination may occur any time temperatures fall below or above the optimum for germination of any particular seed (Copeland and McDonald, 1997). Temperature, especially high temperature, can lead to reduction or inhibition of germination in many seeds. This is especially true of several vegetable and ornamental flower seeds when the temperature rises above 30 °C for extended periods of time. In many of these seeds, this inhibition of germination only lasts as long as the seeds are in an excessively high temperature for germination. Thus, as temperature is reduced towards the germination optimum, the seeds will generally germinate. Many times, reduced night temperatures are not long enough at an adequate temperature to allow germination to occur. Unfortunately, because of several factors including seed quality (vigor), moisture availability, and variability in temperature within a tray, the transplant producer may once again find that seed lots may vary greatly in their emergence capacity. In some seeds such as lettuce, geranium, and impatiens, imposing a high temperature for periods in excess of ≈ 72 h may impose a secondary dormancy called thermo-dormancy (Styer and Koranski, 1997). Geranium and impatiens are inhibited by temperatures in excess of 25 °C and many if not most lettuce cultivars are inhibited by temperatures of 30 °C or more.

AERATION. Adequate aeration is another factor that must be considered to ensure optimum and uniform germination. Transplant producers who use germination temperature control rooms often do not consider this factor when trying to establish uniform emergence. In these cases, the

trays are filled with media and moistened with water then stacked one atop the other to the point that aeration can be limited, especially in the trays anywhere below the top of the stack. Sometimes these stacks will be on a palette from floor to ceiling in excess of 3 m high. Many transplant producers have developed tray styles and stacking procedures which allow aeration at the seed level in each of the trays.

It is generally necessary to cover many seed species during germination with media that will maintain high humidity and moisture, but allow the maximum aeration at the seed level. Such materials as coarse vermiculite, sand, perlite, styrofoam beads or calcine clay could be used to cover the seed. Smaller seeds should not be planted and covered as deep as large seeds.

LIGHT. Many of our crop species do not require light for germination. However, for some crop species, light is a requirement for germination [e.g., tobacco (*Nicotiana tabacum* L.)] (Bradbeer, 1988). In other crop species, light can actually inhibit radicle extension and growth, thus inducing nonuniform seedling growth. This latter case can be exemplified by such species as vinca [*Catharanthus roseus* (L.) G. Don], cyclamen, phlox [*Phlox dummondii* (Hooker)], and lettuce. In other species germination may be improved through the addition of light. Examples of these are lettuce, celery [*Apium graveolens* (L.)], impatiens and petunia (*Petunia* sp.).

Seed testing

A seed testing laboratory can help determine the ability of a seed to grow by reporting percentage of germination. Most seed testing laboratories will test seed for purity, moisture content, and percent germination. Unfortunately, seed laboratories cannot give an accurate idea of how seeds will perform under varying field conditions. They only report how well the seeds will germinate under ideal conditions. Testing laboratories generally use paper towel tests which provide the seed with continued optimum moisture conditions (Copeland and McDonald, 1997). The seeds are then placed in a

controlled temperature germination chamber for that particular species' optimum. Thus, the results of the germination test may be grossly misleading to a transplant producer when crops are grown under environmental extremes.

Seed vigor

Seed testing laboratories generally do not provide tests for seed vigor. Vigor can be defined as the ability of a seed to germinate rapidly and produce a normal seedling under a wide range of conditions (Basra, 1995). Seed vigor is something that cannot be seen or measured until the seed germinates. Even then, vigor measurements are hard to correlate to final yield. There is no one universal vigor test for all seeds. A vigor test can only measure one phase of early seedling growth. Plug or field producers of transplants should test and record germination across all conditions the entire lot will experience in order to determine seed uniformity and total emergence under those varying conditions. This, in most instances, gives a good indication of the potential vigor of that seed lot.

There are several tests that are used by seed companies to measure vigor in the seed lot. Several examples of tests for seed vigor include looking at either cool and/or warm germination stress tests, uniformity and rate of radicle protrusion, measuring radicle growth over a certain period of time, conductivity of seed leachate, accelerated aging, various seedling growth tests such as root length and seedling height, and more recently, a technique developed by the Ball Seed Company utilizing image analysis of cotyledon expansion (Copeland and McDonald, 1997; Styer and Koranski, 1997).

Vigor tests are often used by a seed company to determine which seed lots are strongest and in some instances, predict how long a seed lot will store. Vigor tests can be used by seed companies to determine potential markets in which the lot should be sold. Companies using such tests will generally direct their best seeds to markets which require and will pay for high quality. The grower who purchases seed from these companies generally will find that total stand counts and emergence

uniformity are improved. Seed companies will often charge more for higher quality lots. If poor seed must be removed from a lot, this will increase the price of the remaining seed.

A transplant grower essentially is selling rental space in a transplant house or field. The use of the highest quality seed (highest vigor) will help insure rapid, uniform, and optimum stands of the crop being grown. This translates into greater profits for the transplant producer. High seed vigor can improve the rate and uniformity of germination, the uniformity of germination, and rate of early seedling growth, especially as it translates to plant growth under less than optimum conditions.

Frequently, the seed viability (ability, to germinate) and seed vigor are directly related. Both viability and vigor decline with time. Generally, vigor begins to decline before the producer observes a decline in viability (Basra, 1995). This means that a seed lot which germinates uniformly at 90% may be adversely affected as environmental conditions become more stressful. If a grower is to use this seed lot in later plantings vigor may have decreased. In this case, the seed lot might germinate well (90%) at conditions closer to the optimum, but as stressful environmental conditions ensue, the seed lot may fail to germinate or become very nonuniform in its germination pattern.

Seed storage

The process of aging occurs naturally during storage, but can be artificially accelerated by high temperature and high relative humidity during storage (McDonald and Stanwood, 1989). Optimum seed moisture contents during storage for many crop species is in a range of 5% to 8%. If moisture content drops below the 5% level, storage life and especially seed vigor may be decreased, generally related to a disruption of membrane organization. This process is nonreversible. When seed moisture contents go above 12%, various fungi and insects can grow and reproduce in and on the seed (West, 1986). At this moisture level aging is accelerated because processes of Phase

II imbibition begin but cell division and elongation cannot occur. Thus, seed storage conditions are of prime importance to maintain seed viability and seed vigor, processes that can then relate to seed longevity. Good storage conditions for most seeds is between 5 and 10 °C at ~40% to 50% relative humidity. If relative humidity can be controlled to 30%, seed longevity can be further improved.

Seed companies will store and ship many types of seeds in hermetically sealed containers. This can be in foil packets, cans, or plastic containers. Such sealed containers provide an excellent barrier to moisture movement in and out of seeds. Unfortunately, these storage containers do not maintain a barrier against temperature. Thus, transplant producers are cautioned in all stages of seed movement from the seed companies to the transplant tray to try to maintain optimum temperature conditions. Once these containers are opened, the moisture barriers are removed, and the transplant producer will then have to maintain adequate humidity levels in the storage area in order to maintain seed longevity over an extended period of time.

Many larger transplant producers have temperature and humidity-controlled seed rooms with alarm systems, should either the temperature or humidity go out of the desired range. For smaller transplant producers, the use of a frost-free refrigerator will substitute for a high-tech seed room. When in the refrigerator, seeds should be placed inside a resealable container. When seeds are needed for use, the container should be brought out and maintained closed in a room until the container temperature has equilibrated to room temperature. This prevents moisture condensation inside the container, and on the seeds. Once the seeds are used, the seeds that remain should again be tightly sealed within the container and put back into the refrigerator. Seed storage could be in a waterproof and vapor-proof container such as Tupperware, a mason jar, 5-gal (19-L) or smaller plastic cans where the lid can be sealed. A layer of silica gel could be placed at the bottom of the container, and seeds should always be equilibrated to room temperature

before the container is opened. If the seed is to be used over an eight-hour or longer period, it is recommended that the seed be retained in the container, and only amounts needed during the time of use should be removed from the container.

If the transplant producer suspects that seeds are gaining moisture through the process of moving in and out of the refrigerator, then the moisture content of the seeds should be once again brought down to the 5% or 8% level. This can be done by placing the open container in a room at low relative humidity or by using a thin layer of silica gel as a desiccant in the bottom of the storage container. In summary, it is recommended that the seed storage container be equilibrated in an air conditioned room or an area with lower relative humidity, and then when needed, move the seed into the transplant area.

Many times transplant producers set up a seed room as part of a controlled climate room or a walk-in cooler. Home-use dehumidifiers are not suitable for controlling moisture content in these rooms, because they will freeze up at temperatures below 17 °C and they also add heat into the room. Germination should be routinely checked for seeds that are stored for periods of 6 months or more. The transplant operator should determine whether or not a seed lot should be retained if germination and/or the ability to germinate under stressful conditions becomes a problem.

Seed pathogens, pelleting, and enhancements

Transplant producers should be continually aware of the problems related to seedborne pathogens in reducing stand and potentially spreading through the transplant production area (Agarwal and Sinclair, 1997). For this reason it is recommended that seeds be used which have been treated with various fungicides labeled for those seeds. Further, the use of film coating will ensure safe conditions for the transplant operator by reducing chemical dust in the atmosphere.

Where high-volume precision placement of the seed is required, it is recommended that the seed be pelleted

(Copeland and McDonald, 1997; Styer and Koranski, 1997). The coatings used in pelleting are generally some type of clay mixed with a binder and/or water. The plug producer should only purchase pelleted seed that has been recently coated. Seed storage conditions for pelleted seeds are the same as for regular seed. In some instances, and for some species, pelleted seeds may not last as long as conventional seeds.

Certain seed enhancement treatments can improve the rate of germination and the uniformity of germination, especially under less than ideal conditions. Primed seed are presently being sold by many seed firms. Seed priming refers to hydrating a seed under controlled conditions, permitting the initial germination processes to begin, while preventing the radicle from emerging through the seed coat (Styer and Koranski, 1997). During priming, the moisture content may increase to 40% or 50%. Generally, cell division and/or cell elongation do not take place during the priming process. Most importantly, after priming the moisture in the seeds is reduced to the initial content of between 5 and 8%. Primed seeds can then be packaged as normal nonprimed seeds and be shipped and planted using conventional seeding equipment. Unfortunately, seed storage time is often reduced in primed seeds. Also, seed priming increases the rate of germination and generally the uniformity of germination under a wider range of conditions, but does not increase total germination under ideal conditions. In other words, seed priming cannot make dead seeds come alive. The variables which are controlled in priming include the amount and the rate of water uptake, temperature, and duration of the process. Seeds which require light to germinate should be given light during the priming process. At all times, oxygen should be made available to the seeds because the seed is a living entity and requires oxygen for respiration.

In summary, understanding seed germination is extremely important to the transplant producer. Optimizing seed germination is the most important step to help ensure economic returns in the transplant operation. Germination

is important and dictates final stands that the transplant operator will achieve, but also the uniformity of emergence will ensure a high quality crop for the transplant producer. The use of high-quality seeds will help optimize these processes.

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