**Germination:**

Germination is the emergence and the development from the seed of those structures which indicates its ability to develop in to a complete plant when favorable conditions are provided. Technically germination is the resumption of active growth that results in rupture of seeds coat and emergence of seedling.

**Events of germination process:**

Germination includes the following physiological and morphological events.

1. Imbibition and absorption of water
2. Hydration of tissues and food
3. Absorption of oxygen
4. Activation of enzymes
5. Transport of hydrolyzed molecule to the embryo axis
6. Increase in respiration
7. Initiation of cell division and enlargement
8. Embryo emergence

For the growth of the embryo axis, the initial growth rate of radicals is more rapid than that of plumule and it is generally the first to emerge from the ruptured seed coat. Dry weight of seedling decline for about 10 days due to respiration losses. Growth sequences with growth preceding top growth to have survival advantages for a seed.

**Hormones involved in germination:**

1. **Gibberelline:**

Activates the hydrolytic enzyme of digestion.

1. **Cytokinins:**

Stimulate the cell division, resulting in radical and plumule emergence. The initial expansion of coleorhiza (emerging root tip) is primarily by cell enlargement.

1. **Auxin:**

Promotes growth by enlargement of coleorhiza (radical) and plumule and by activation of geotropism (i.e. correct orientation of shoot growth irrespective of seed orientation).

**Metabolism of stored food:**

Germination and seedling emergence have a high demand for energy via respiration of seed food reserves. The energy in the chemical bond of carbohydrates, fats and proteins are released by digestion and oxidative phosphorylation which provide energy rich nucleotides, such as adenosine triphosphate ATP in mitochondria. As ATP is converted to ADP energy is released for biological activates.

Carbohydrate, fats, proteins ADP+P ATP degradation product ATP ADP +P1  biosynthesis

Starches are hydrolyzed by α and β-amylase mediated by gibberellins to maltose and glucose sugar.

Some glucose is converted by enzyme invertase to sucrose the sugar commonly transported by plants. Glucose is metabolized by:

1. Glycolysis which form two molecules of pyruvic acid and ATP.
2. Oxidation by the kreb cycle or tri carboxylic acid cycle which can completely oxidize the acid into CO2 , H2O and ATP.

Fats are hydrolyzed by lipase into glycerol and fatty acid. fatty acid is further degraded by per oxidase and aldehydogenase in α oxidation, which removes successive carbon atoms to yield CO2 and stored energy(NADPH). A more common degradation of fatty acid is in β oxidase which split the fatty acid into 2 carbon unit (acetyl COA) and ATP. Acetyl COA may enter the kreb’s cycle for further oxidation and production of ATP.

Protease breaks peptide bonds in protein molecule, yielding amino acids. Fate of amino acid is as follows:

1. Amino acids resynthesis in growth Proteins
2. Amino acids transmination Organic acid
3. Amino acids hydrolysis Organic acid and ammonia

Organic acid residue enters the kreb cycle for further oxidation.

**Germination requirements and factors affecting germination process**

**Environment:**

Water nonrestrictive temperature and suitable atmosphere are required for germination of non-dormant or after ripened seeds. Generally, condition favoring growth of seedling also favors germination. Seeds of different species, however varying degree of genetically or environmentally imposed dormancy. Germination does not occur until referred to as after ripening (the loss of such dormancy, through exposure to certain environmental condition for a sufficient length of time).

**Water:**

Imbibition of water is the first process in the seed germination. Live and dead seed imbibed water and swell. The amount imbibed is related to the chemical composition of seed. Protein, mucilage and pectin are more colloidal and hydrophilic and imbibed more water than starches. Cereal grain such as maize imbibed more water to approximately one third seed weight, soy beans to one half seed weight. A soil moisture level of field capacity is generally optimum for germination. Germination proceeds at slower rate as soil moisture near the wilting point. Less than optimum water content usually results in partial imbibition and slowed or arrested germination. Composition of medium particularly the solute content affects water availability, as the osmotic concentration was increased water availability decreased, but specific ion, especially sodium and magnesium affect germination more than water availability.

**Temperature:**

Except imbibition, germination involves a number of enzymatically controlled processes of catabolism and anabolism and hence is highly responsive to temperature (maximum, optimum and minimum). For germination of most crop seed is essentially those of normal vegetative growth. The optimum temperature is that give normal highest germination percentage in the shortest period of time. Non after ripened seeds with a partial or relative dormancy germinated in a narrow range of temperature, like 5⁰C-15⁰C for low temperature species. Cardinal temperature for germination of different crop seeds overlap, but germination rate of all is slower at low temperature.

Temperature range in which germination occur in different seeds are

| **SEEDS** | **TEMPERATURE (**⁰C **)** | | |
| --- | --- | --- | --- |
|  | **MIN.** | **OPT.** | **MAX.** |
| CORN | 8-10 | 32-35 | 40-44 |
| RICE | 10-12 | 30-37 | 40-42 |
| WHEAT | 3-5 | 15-31 | 30-43 |
| BARLEY | 3-5 | 19-27 | 30-40 |
| RYA | 3-5 | 25-31 | 30-40 |
| TOBACCO | 10 | 24 | 30 |
| OAT | 3-5 | 25-31 | 35-40 |
| FIELD BIND WEEDS | 0.5-3 | 20-35 | 35-40 |

Some of seed species such as cotton and tobacco are very sensitive to chilling during germination. Seeds of some wild species or those with a short domestication history have a relative dormancy that is responsive to temperature.

**Gases (O2):**

Germination requires a high level of O2 unless respiration associated with it by fermentation. Most species respond best to the ambient composition of the air, 20% O2 and 0.03% CO2 and 78% N2. Decreasing the O2 content below 20% usually decreases germination. Seed germination in most species is favored by an ambient or higher oxygen concentration. Generally poor drained soils provide an atmosphere less than optimum for germination.

**Light:**

Seeds of many species require light for germination has been known and classified several hundred species according to light requirement.

1. Germination was favored by light
2. Germination favored by dark
3. Germination was unaffected by dark or light

Seed in the first category is said to be photoblastic. The ecological significance of light in germination is understandable, since many weed science germinate only after light exposure at the soil surface, such as that induce by the soil disturbance. Exotic in a forest ecosystem germinate only after the land is cut over and disturbed by harvesting operations, exposing theses seeds to light.

Germination of crop seeds with relatively long domestication histories (except for tobacco, lettuce) is generally non photoblastic. Lettuce seed germinate readily with light or if after ripening by a special set of condition.

The quantity (energy level), quality (color or wavelength) and duration of light (photoperiod) in the cycle has a marked influence on germination depending on the species. Generally light at low energy level (1/50-1/100 full sunlight) is adequate to stimulate germination. Like flowering, germination in many species is also responsive to photoperiod depending on the species is favored by short day or long days or is day neutral. The effect of light quality on light sensitive seed is pronounced as shown:

|  |  |  |
| --- | --- | --- |
| **WAVELENGTH (nm)** | **COLOUR** | **RESPONSE** |
| <290 | Ultraviolet (invisible) | Inhibition |
| 290-400 | --do-- | No clear cut effect |
| 420-500 | Blue (visible) | Inhibition |
| 560-700 | Orange red (visible) | Promotion |
| >700 | Far red (invisible) | Inhibition |

The most effective wavelength for promoting and inhibiting seed germination were reported to be red (peak at 660nm) and infrared (far red 730nm) respectively.

After the early work the investigator found that the pigment phytochrome was the light receptor controlling the response. This is the protein that exist in two inconvertible forms forms Pr and Pfr, Pr appears blue and Pfr a faded shade of blue which become evident after exposure to red light. A proposed mechanism for seed germination is as follows

Reactant red

Pr Hormone product Hydrolytic

Far red

enzyme activity germination

Pr\_\_\_\_\_\_\_\_\_\_\_\_\_\_Pfr--------Germination

Pfr is believed to be biologically active form of the controlling mechanism in germination and in other plant phytochrome responses.

**Exogenous chemicals:**

A number of chemical in the medium promote germination of same species. They can be regarded as stimulators rather than germination requirements. Certain chemicals such as gibberellins can enhance or substitute for the light or cold requirements for after ripening.

1. **Potassium nitrate:**

It is used routinely in germination tests of many grass seeds and generally on photoblastic seeds.

1. **Thiourea CS(NH2)2:**

It is not extensively used but does stimulate germination in certain species. It cannot substitute light or temperature requirements of seeds.

1. **Hydrogen per oxide (H2O2):**

Effective on seed of some legumes, tomato and barley.

1. **Ethylene:**

Stimulate germination in different species and increase the girth of the germination seedling axis.

1. **Gibberellins (GAs):**

It can substitute at least partially for light and cold in photoblastic seeds. GA3 is most commonly used but GA4, GA7 are found to be more effective.

**Maturity:**

even in favorable environment, germination cannot occur until a minimum level of morphogenesis in seed. Generally sufficient development for viability and germinability occur long before seed maturity.

**Longevity:**

Duration of viability of seed longevity depends on genotype, dormancy mechanism and the storage environment. Seeds of most crop plant maintain viability for many years germination 70-90% after 7-10 years if stored in suitable conditions.

During storage low temperature, low humidity and low oxygen are favorable conditions. A general rule is that sum of values of ambient RH (%) and temperature (F) of the storage environment should not exceed 100. For example 40F and 40% RH  (totally 80) should constitute good storage condition, but lower temperature and humidity should be superior.

**Seed dormancy:**

Dormancy, a suspended state of growth or rest is a condition that may persist for an indefinite period of time despite conditions favoring germination. Technically seed is dormant at a point of physical and physiological separation from the mother plant. This intermediate dormancy ceases however with the new set of condition favoring germination.

Condition that prevent resumption of growth by a viable embryo when placed under a favorable condition that promote germination of non-dormant seed.

Species remain viable and ultimately germinate despite serve stress from temperature, water, fir, cultivation and animal and bird digestion.

**Types of dormancy:**

Two main types of dormancy:

1. Primary dormancy
2. Secondary dormancy

**Primary dormancy:**

Some seeds are dormant when they leave the parent plant therefore this dormancy is genetically controlled and inherited from the parent plant and is property of seeds. E.g. dormancy in *Arena fatua*

This type of dormancy is characterized by:

1. **Rudimentary embryo:**

The outside of seed may appear fully developed but it may have physical immature embryo that need more growth before the seed can germinate. Therefore, the seed appear mature although the embryo is slowly growing and developing.

e.g. seeds of Typha spp. And Polygonum spp. (dumb grass) show this characteristic.

1. **Physiological immature embryo:**

In some weed spp. The embryo is completely developed but do not germinate and germination occur after a period of after ripening which is a physiological change in stored substances, appearance of germination promoting substance or disappearance of germination inhibiting substance. Occasionally cool temperature for several months will end this type of dormancy. This type is immature embryo is common in parasitic seed plants such as witch weed. This type of dormancy is common in grasses, mustard, and polygonum spp.

1. **Impermeable seed coat:**

A hard seed coat is the principal dormancy mechanism in legume seed, water impermeability of legume seed results from two factors.

1. A seed coat with a densely pack layer of scleroid malphagian cells at right angle to the surface of the testa plus phenolic or other water repellants compounds; such are common in legume seed coat.
2. Closure of natural openings in the seed coat, which include the micropyle, funicle and pleugram (a dispersion below the micropyle and funicle). Olveral et al (1982) concluded that main factor responsible for the hard seed in levcaena (legume) is pleugram closure. These structure close as the moisture level outside the seed becomes lower than inside, allowing moisture to leave but not to enter.

The hull of many grass seeds and weedy species, such as green needle grass and Indian rice grass are impervious to oxygen. In green needle grass the lemma and palea (seed hull) act as barrier. The cocklebur seed is actually a spiny, dry, non-dehiscent fruit containing two seeds, the lower seed may germinate readily while the upper one remain dormant for several years because of low oxygen tension surrounding it. Hull of wild oat also imposed a low oxygen tension. Removal of these hulls of the seed of both these plants greatly improves germination.

This type of dormancy is particularly found in families of leguminosea, chinopodiaceae and solanacea.

1. **Mechanically resistant seed coat:**

Mechanically resistant seed coat can imbibe water readily, unlike hard seed, but resistant swelling and embryo protrusion. Seed of some weeds, grasses and most spp. with hard seeded fruit (nuts) as seed have seed coat mechanically resistance to embryo emergence.

1. **Physiological dormancy:**

Physiological dormancy is often referred to an embryo dormancy and has been called deep dormancy. The presence of growth inhibitors, the deficiency of growth promoting substances or a lack of proper balance between these hormones has been postulated as the factors causing embryo dormancy. Abscisic acid and coumain and other inhibitors(table) have been shown to induce dormancy but these factors may be in the hull, seed coat, aleuron or embryo. Growth promoting substances (GAS and cytokinins) released dormancy in wide variety of species.

In seed as a result of reaching a balance of growth promoters and growth inhibiting hormones.

I

Simultaneously increasing growth promoting and decreasing growth inhibiting hormones.

Increasing growth promoting hormone while growth inhibiting hormones remain static.

Decreasing growth inhibiting hormone while the growth promoting hormones are constant.

P

P

P

I

I

concentration

concentration

concentration

Coumains is natural chemical inhibitors in physiological dormancy, but ABA, unsaturated lactones, alkaloids, phenol, ethylene, ammonia, essential oils, hydrocyanic acid and organic acid also have been reported to cause dormancy. Growth inhibitors controlling dormancy may be in embryo, as in number of grasses, in the hull, as in the lettuce and buck wheat; or in the fruit, as in apple or tomato.

**Treatments for breaking dormancy:**

1. **For hard seed coat impermeable:**

A large number of after ripening treatments are effective in breaking hard seed coat dormancy.

* Strong acid and alkalis are highly effective but can also damage the seed.
* Heat at 100⁰C for 1.5 minutes as delivered by a 250 w infrared lamp or hot water is effective in reducing hard seed contents.
* Hot water 100⁰C for 5-20 sec caused the pleurogram in leucanea to open and resulting germination of 95-100% depending on variety.
* Scarification (mechanical abression, acid or hot water treatment of seed coat) can remove hilum plugs and increase permeability.
* Laboratory chilling and KMnO3 solution treatment induced nearly complete germination in green needle grass in which lemma and palea act as barrier for O2.
* Alternate cycle of temperature or hydration make the seed coat permeable by concentration and expansion on the weak side in permeable coats.
* Sometime incubation of intact seed in high oxygen tension increases germination.

1. **For mechanical hard seed coat:**

* A prolonged period of wet storage can weaken the hard seed coat and accomplish after ripening.
* In case black walnut several week of cold at 2-5⁰C wet storage (stratification) are required.
* Mechanical injury cut or puncture the seed coat over or near radical or even complete or removed seed coat stimulate germination.

1. **For physiological dormancy:**

* Amen stated (1963) that most of the dormancy mechanism can be broken by growth promoting substances. So that the treatment of seed with GAS break the dormancy because GAS replace the light requirement innumerous photoblastic seed (lettuce, tobacco) and cold requirement in species requiring stratification (wild oat, many tree species).
* Varying degree of dormancy found in ten varieties of wheat where due to water or methanol-soluble growth inhibitor, which disappear after a month or so of dry warm storage.
* Leaching of hull removal increases germination certain grass species. In sorghum, dormancy has been associated with brown pericarp fused with tesla. The dormancy factor was removed scarification or by hot water treatment. The endosperm and aleuron of certain species also contain dormancy factors. The embryo and pericarp wild rice contained inhibitory level of ABA which was removed by more than 100 days of cold water 3⁰C storage.

**Secondary/induced dormancy:**

The dormancy which is not inherited from parent plant, this type of dormancy developed spontaneously in seed due to changes occurring in them. These changes may be reverse of those during after ripening. Sometime secondary dormancy is induced when given all the condition required for germination except e.g.

* The failure of light to light requiring seeds.
* Too high or too low temperature for germination may also induces secondary dormancy as imbibed germinated seed become dormant if exposed to high temperature (30-35⁰C).
* Low oxygen tension will cause secondary dormancy cocklebur (xanthium spp. , muhabat booti).
* High carbon dioxide concentration may cause secondary dormancy in Brassica.
* primary dormancy is easy to break but secondary is difficult to break.