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Factors That Cause Seed Dormancy

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Abstract

Seed dormancy is a state in which seeds do not germinate despite the presence of all of the necessary conditions (temperature, humidity, oxygen, and light). It is caused by hard seed coat impermeability or a lack of supply and activity of the enzymes required for germination. The dormancy of seeds presents a practical problem of considerable economic importance. Plant growers are often interested in securing seed that will germinate soon after it is harvested. To overcome dormancy, organic material is subjected to a variety of physical and chemical pretreatments. Some plant species have both physical and internal dormancy, making it difficult to produce high-frequency healthy seedling growth, despite the fact that seed sprouting and the generation of healthy seedlings is a requirement for plant output. The Chapter is intended to present the basic information on the seed dormancy which would be of relevance to the seed growers and scientists during seed handling process. Seed dormancy is of great concern to scientists therefore it is a research area of interest. All the viable seeds have capacity to germinate if placed under suitable conditions necessary for germination. But some seeds fail to germinate for sometimes even if placed under the condition favorable for germination.

Keywords: seed coat, seed dormancy, seed germination, types of seed dormancy, breaking seed dormancy, factors responsible for seed dormancy

1. Introduction

The history of seed is the evolution of crop cultivation for human sustenance and survival. Over time this progression had been achieved through introduction, development and release of varietal of seeds using various well-known techniques of selection, hybridization and polyploidisation. However, all these stages of seed development have little value if main aim of seed development is not achieved due to a block to the completion of germination widely known as seed dormancy. Seed dormancy is an inactive status of seed and its property that normally describes the environmental factors in which the seed would germinate. This phenomenal is determined by both seed genetics, hormones, and substantial environmental influence in seed maturation environment. However, seed dormancy could be considered simply as a block to the completion of germination of an intact viable seed under
favorable conditions [1–3]. All climatic regions have cases of seed dormancy but with varying divergent responses in adaptation to avoid hostile climate conditions for germination. The adaptation is timed to avoid unfavorable weather for germination and subsequent plant establishment and reproductive growth. All viable seeds have the ability to sprout when placed in the proper germination circumstances. However, some seeds, even when placed under ideal conditions for germination, fail to germinate. This could be due to internal reasons or a necessity for specific external conditions. During this time, the seeds’ growth is halted, and they are said to be in a rest or inactive state, and this occurrence is known as seed dormancy [4]. Seed dormancy is among the least implicit phenomena in the field of seed biology particularly with the issues of clear description, unambiguous definitions and distinct types and classifications of the seed dormancy as well as the vital distinction of the different methods to terminate dormancy or induce germination and factors responsible for the mechanisms. In this chapter an attempt is made to discourse these issues in perspective of types and methods of breaking seed dormancy and factors responsible for dormancy.

2. Meaning of seed dormancy

2.1 Definitions of seed dormancy

Seed dormancy is an internal condition of a viable seed which constraint its germination despite enable growing conditions of suitable temperature and moisture availability [4]. Therefore, seed dormancy can be simply described as a resting state of a viable seed that must be broken either by time or deliberate conditions before the seed germinates at temperature and moisture levels suitable for required growth. In operational term, dormancy is a block to the completion of germination of an intact viable seed with suitable growth conditions. The block evolves based on the species of the seeds and climatic conditions in the prevailing environment [5–8]. Also, seed dormancy is a state in which seeds do not germinate despite the presence of all of the necessary conditions (temperature, humidity, oxygen, and light). It is caused by hard seed coat impermeability or a lack of supply and activity of the enzymes required for germination. Dormancy is a significant limiting factor in the production of many field crops. To overcome dormancy, organic material is subjected to a variety of physical and chemical pretreatments. Some plant species have both physical and internal dormancy, making it difficult to produce high-frequency healthy seedling growth, despite the fact that seed sprouting and the generation of healthy seedlings is a requirement for plant output. However, the constraint in definitions of the seed dormancy is inability to observe it in no other measure than the absence of germination [9, 10]. This is because a state of dormancy can take a value between maximum dormancy and non-dormancy. Therefore, dormancy is not typically associated with the absence of germination in seed rather it is a characteristic of the seed that determines the conditions essential for germination.

2.2 Seed dormancy and germination

A dormant seed has no capacity to germinate even in the presence of favorable environmental factors and habitable conditions due to either non-viable, empty of embryo or dormancy [4, 5]. Many types of seeds, even when they appear to be ripe,
Factors That Cause Seed Dormancy
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fail to germinate even when all environmental parameters are favorable. The embryo's resumption of growth in such seeds is halted by the circumstances within the seeds. The state of slowed growth of seeds or other plant organs caused by internal factors is known as dormancy, but it is also known as the rest period. Seed dormancy is of considerable advantage to the plant. It enables the embryo to safely pass the unfavorable part of the year and germinate when the conditions are suitable for the establishment of the seedlings [3, 5]. In nature, dormancy period coincides with the unfavorable period for the seedling of the species. In other words, a completely non-dormant seed has the capacity to germinate over the widest range of normal physical environmental factors possible for the genotype. Therefore, a suspected case of seed dormancy arises when fresh un-germinated seeds remain at the end of a germination trial period that required some particular conditions of either endogenous, exogenous or combination of both factors to be satisfied. For seed to germination there are needs for basic requirements of water, oxygen and appropriate temperature, in consideration of other factors such as light and hormones. However, seed germinations are generally in three phases, starting with the uptake of water by imbibition of the dry seed which leads to embryo expansion [11–14].

First phase: This phase is known as Imbibition where there is rapid initial water uptake by the hard seed in the process of hydration of protoplasm which would be followed by activation and synthesis of enzymes.

Second phase: This is plateau phase where increase in water uptake leads to increase in respiration of embryo preceding activation and synthesis of enzymes. This increase synthesis of nucleic acids and proteins with release of hormones from the embryo.

Third phase. This is embryo elongation phase. It's a point where radicle protrusion which is generally accepted to be sufficient for completion of germination is visible. This stage entails increased cell enlargement, cell division hydrolysis of reserve food and utilization of soluble organic substance by developing embryo for the growth of the radicle into root and plumule into shoot.

3. Types of seed dormancy

There are several categories of seed dormancy classification in literatures. However, seed dormancy may be classified based on the following schemes [15];

i. Mode of seed origin

ii. Mode of seed structure

iii. Mode of action

- **Mode of seed origin:** Based on the seed provenance dormancy can be classified into two main groups;

  a. **Primary dormancy:** this is an inherent dormancy status of a maturing seed when its fully developed on the parent plant. This is when the seed is released from the mother plant in a dormant state.
b. **Secondary dormancy:** This is when the seed released from a parent plant becomes dormant as a result of environmental conditions. This is regarded as induced dormancy whose germination of the seeds have been inhibited. Secondary dormancy develops in some non-dormant and post-dormant seeds exposed to unfavorable germination conditions, such as high temperatures. It’s brought on by circumstances that arise after the seed has been disseminated. The mechanisms of secondary dormancy are unknown; however, they may entail the reduction of sensitivity in plasma membrane receptors. Many species of plants release their seeds late in the year when the soil temperature is too low for germination or when the environment is too dry for germination. These seeds will germinate if they are gathered and sown in an environment that is warm and/or moist enough. Non-dormant seeds released late in the growing season in natural settings season, wait until the soil temperature rises in the spring, or in the event of seeds scattered during dry seasons, wait until it rains and the soil is sufficiently moist [16–18].

- **Mode of seed structure:** Seed dormancy can be categorized into two main groups based on the parts of the seed where the dormancy affects and control.

  a. **Embryo induced dormancy:** the dormancy is within the embryo itself and usually caused by undeveloped or complete dormant embryo

  b. **Coat induced dormancy:** This is the dormancy which resides within the structure (seed coat) enclosing the embryo and caused by extreme hardness of the seed coat.

- **Mode of action:** This mode of classification is based on the action of dormancy that is shown to be determined by both the physiological and morphological properties of the seed.

Generally, seed dormancy could either be exogenous or endogenous dormancy.

### 3.1 Exogenous dormancy

**Exogenous dormancy** is caused by conditions outside the embryo and is often broken down into three subgroups [19–22]:

i. **Physical dormancy:** this is caused by impermeability of layers of macrosclereid cells and mucilaginous outer cells to water. The movement of water is restrained by hardened endocarp of the seeds. This happens when seeds are impervious to water or gas exchange. Legumes are a good example of physically inactive seeds since they have a low moisture content and the seed coat prevents them from absorbing water. Water can be absorbed by chipping or splitting the seed coat or other coatings. Impermeability is frequently generated by an exterior cell layer made up of macrosclereid cells or a mucilaginous cell layer. A stiffened endocarp is the third source of seed coat impermeability. During the latter stages of seed development, seed coverings that are impervious to water and gases form.
Factors That Cause Seed Dormancy
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ii. **Mechanical dormancy**; when seed coats or other coverings are too tough to allow the embryo to expand during germination, this happens. Previously, this method of dormancy was ascribed to a number of species, however endogenous components were discovered to be responsible for their hibernation. Physiological dormancy caused by poor embryo development potential is one of these endogenous facts.

iii. **Chemical dormancy**; this includes growth regulators found in the embryo’s surrounding tissues. They can be washed or soaked out of the seed’s tissues, or they can be deactivated in various ways. Rainwater or snowmelt removes other compounds that hinder seeds from germinating.

3.2 Endogenous dormancy

*Endogenous dormancy* is divided into physiological dormancy, morphological dormancy, and combined (morpho-physiological) dormancy, and is typically triggered by factors within the embryo itself [23–25].

i. **Physiological dormancy**; this is the most common type of seed dormancy in seed biology. An embryo growth is retarded due to inhibitors changes and seed germination prevented. It is as a result of seed not satisfying certain physiological conditions necessary for germination. Physiological dormancy stops embryos from growing and seeds from germinating until chemical changes take place. Inhibitors are among these compounds, and they often slow embryo growth to the point where it is unable to break through the seed coat or other tissues. An increase in germination rate following the application of gibberellic acid (GA3) or after Dry after-ripening or dry storage indicates physiological dormancy. It’s also useful when latent seed embryos are removed and healthy seedlings result; or when up to 3 months of cold (0–10°C) or warm (>15°C) stratification improves germination; or when dry after-ripening reduces the time spent cold stratifying. Scarification increases germination in some seeds, indicating physiological dormancy.

ii. **Morphological dormancy**; this manifests in seeds with embryos that are under developed in size but clearly with differentiated cotyledons, hypocotyls and radical axis. The embryos in morphological dormancy are normally under favorable conditions only require time to grow and germinate because they are not physiologically dormant. Underdeveloped or undifferentiated embryo. Some seeds have completely developed embryos that need to expand more before seed germination, whereas others have embryos that have not yet differentiated into distinct tissues when the fruit ripens. Immature embryos - certain plants release their seeds before the embryos’ tissues have fully differentiated, and the seeds ripen after they take in water while on the ground; germination might take weeks or months.

iii. **Combined (Morpho-physiological) dormancy**; Combined dormancy occurs in some seeds, where dormancy is caused by both exogenous (physical) and endogenous (physiological) conditions. This is a dormancy where the seeds have under development in size but distinctly differentiated embryos in addition to components of physiological dormancy. The seeds under this dormancy
require time to enable the embryo to grow and germinate as well as dormancy breaking treatment. Seeds are dormant both morphologically and physiologically. Morpho-physiological dormancy, also known as morphophysiological dormancy, occurs when seeds with immature embryos exhibit physiological dormancy. As a result, dormancy-breaking procedures and a period of time to generate fully formed embryos are required for these seeds.

a. Intermediate simple
b. Deep simple
c. Deep simple epicotyl
d. Deep simple double
e. Intermediate complex
f. Deep complex

4. Methods of breaking seed dormancy

Various methods have been used by seed scientist and technologists to break the dormancy of seed. Simple and widely used methods are [26]:

4.1 Scarification

*Scarification*; is a term used to describe any physical or chemical treatment that weakens the seed coat. When a hard seen coat imposes dormancy, such as in legumes like Cajanus cajan (tur), gram, and others, the scarification method is used. There are several ways to shatter the hard seed coat with this procedure, including [26–28]:

1. The seeds are manually rubbed on sand paper. When rubbing seeds such as green gram and subabool, care should be taken not to injure the axis of the seed.
2. When the seed coat is too hard, especially if it is of a woody type, the seed coat must be broken off completely. Rubber (Havea spp.) seed, for example, is used to make India teak wood.
3. Soaking treatment: Eliminates seed coat impermeability by soaking hard seed coats in a concentrated or diluted sulfuric acid solution for 1 to 60 minutes. Cotton seeds, for example, and India teak wood seeds.

4.2 Temperature treatments

*Temperature Treatments*; when dormancy is caused by embryo factor, the seed is incubated at a low temperature (0–5°C) on a substratum for 3 to 10 days, allowing it to reach its optimum temperature. Germination necessitates the presence of this ingredient. - Take mustard, for example (Brassica campestris). Before germinating at the proper temperature, some seeds required a brief period of incubation (from a few
Factors That Cause Seed Dormancy
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hours to one to five days) at 40 to 50°C. (When using this approach, make sure the seed has a moisture level of no more than 15%, for example, paddy) (Oryza sativa). Breaking hard-seed ness in legumes with hot water treatment is also an effective strategy. The seeds are steeped in water at a temperature of 80°C for 1–5 minutes in this approach before putting for germination (depending up on the type of seed) [29].

4.3 Light treatments

Light Treatments; some seeds do not germinate in dark thus are providing with continuous or periodic exposure of light is essential for example Lettuce (Lactuca sativa) required red light (660 nm) or white light is essential for germination to occur [20].

4.4 Treatments with growth regulators and other chemicals

Treatments with growth regulators and other Chemicals; the presence of germination inhibitors may cause endogenous dormancy. Low-dose growth regulators (Gibberellins, Cytokinins, and Ethylene) may be used to break seed dormancy. Gibberellins and kinetics are the most extensively utilized growth regulators; for example, presoaking seed treatment with GA3 at a concentration of 100 ppm has been employed to break seed dormancy in sorghum seeds. Potassium nitrate (0.2 percent) and thio – urea (0.5 to 3 percent) is commonly used to break seed dormancy in oat (Avena sativa), barley (Hordeum vulgare), and tomato (Solanum lycopersicum) (Solanum Lycopersicum) [30].

Several methods have been devised for breaking the dormancy of seeds and for shortening the period of dormancy so that they may germinate promptly. Whenever dormancy results of any of the causes inherent in the seed coats it can be interrupted by scarification. For example, machine thrashed legumes seeds usually show a higher percentage of germination than those that have been harvested by hand. Strong mineral acids have been used successfully to interrupt seed dormancy caused by resistant or impermeable seed coats. Soaking the seeds in certain chemicals like potassium nitrate, ethylene, chlorohydrine, thiourea or in certain plant hormones is known to break dormancy. After ripening of many seeds occurs more rapidly when they are kept at low temperatures than when stored at higher temperatures. Temperatures from 5–10°C for two or three months are effective with seeds of conifers. Under natural conditions, seed dormancy is gradually overcome by processes such as weakening of the seed coat by the digestive juices in the alimentary canal of fruit-eating birds and other animals, or in still due to the action of microbes or due to mechanical abrasions. Dormancy of seeds is also broken by subjecting the seeds alternately to relatively low and high temperatures. Light is also considered as means of breaking dormancy of seeds. Seeds of sweet clover (Melilotus alba) and alfalfa (Medicago sativa) showed greatly improved germination after being subjected to hydraulic pressures of 2000 atmosphere at 18°C. The following are some general approaches for breaking seed dormancy [31–33]:

1. **Dry storage:** It is often sufficient to store the sample in a dry spot for a short amount of time for species where dormancy is naturally short.

2. **Pre-chilling:** The germination duplicates are placed in contact with the moist substratum and held at a low temperature for a length of time before being raised to the appropriate temperature.
3. **Pre-heating:** The germination replicates should be heated for up to seven days at a temperature of not more than 40°C with free air circulation before being placed under the appropriate germination conditions. It may be essential to lengthen the pre-heat duration in some circumstances.

4. **Light:** The seed should be illuminated during at least 8 hours in every 24 hours cycle and during the high temperature period when the seeds are germinated at alternating temperatures. The light intensity should be approximately 750–1250 lux from cool white lamps.

5. **Potassium nitrate (KNO$_3$):** The germination substratum may be moistened with a 0.2 per cent solution of KNO$_3$, prepared by dissolving 2 gm KNO$_3$ in one liter of water. The substratum is saturated at the beginning of the test, but water is used for moistening it thereafter.

6. **Gibberellic Acid (GA$_3$):** The germination substratum may be moistened with 500 ppm solution of GA$_3$, prepared by dissolving 500 mg GA$_3$ in one liter of water. When dormancy is weak, 200 ppm may be sufficient. When the problem is severe, a 1000 ppm solution may be utilized. When the concentration is greater than 800 ppm, a buffer of 0.01 M in distilled water can be employed.

7. **Pre-washing:** When germination is affected by a naturally occurring substance in the seeds, which acts as an inhibitor it may be removed by washing the seeds in running water at room temperature (25°C) before the germination test is made. After washing the seeds should be dried back at room temperature (25°C).

8. **Removal of structures around the seed:** Germination can be promoted by removing outer structures such as involucres of bristles or lemma.

9. **Disinfection of the seed:** A fungicide treatment may be applied before planting the seed for germination, when the seed is known not to have received such a treatment.

10. **Soaking:** Seeds with hard seed coats may germinate more readily after soaking for 24–48 hours in water. The seed should be planted for germination immediately after soaking.

11. **Mechanical scarification:** Breaking the dormant condition may be as simple as piercing, chipping, filing, or sand papering the seed coat. Scarifying the seed coat at a proper location is necessary to avoid harming the embryo and the resultant seedling. The region of the seed coat directly above the cotyledon tips is the optimum location for mechanical scarification.

12. **Acid scarification:** With some spices of seeds steeped in concentrated H$_2$SO$_4$ until the seed coat becomes pitted, digestion in concentrated H$_2$SO$_4$ is successful. Digestion may be rapid or take more than one hour but the seeds should be examined every few minutes. After digestion, seeds must be thoroughly washed in running water before the plant for germination.
Factors That Cause Seed Dormancy

5. Factors responsible for seed dormancy

5.1 Impermeability of seed-coats to water

The seed coats of many species are completely impermeable to water at the time of their maturity. This condition is very common in the seeds of many legumes, (example, clovers, alfalfa) of the water lotus, and of the morning glory. Germination fails to occur until water penetrates through the seed coats [28–32, 34].

5.2 Mechanically resistant seed coats

In some seeds as those of mustard (Brassica), pigweed (Amaranthus), shepherd’s purse (Capsella), the seed-coats are so strong that they do not yield to the pressure of the expanding embryo. The embryos of these seeds have no dormant period and will grow readily if the seed coats are removed.

5.3 Seed-coats impermeable to oxygen

The two seeds in a cocklebur (Xanthium) fruit are not dormant in the same way. The lower seed normally germinates in the spring following maturity in natural settings, while the top seed remains dormant until the following year. The impermeability of the seed coverings to oxygen has been shown to be the cause of dormancy in these seeds.

5.4 Rudimentary embryos

In plants like ginkgo (Ginkgo biloba), European ash (Fraxinus), holly (Ilex) and many orchids, the embryo is unorganized when the seed is shed and attains full development before it germinates.

5.5 Dormant embryos

Even when the embryos are fully grown when the seed is ripe, many species’ seeds fail to germinate, even when the environmental conditions are ideal. The physiological state of the embryo causes dormancy in such seeds. Even if the seed coverings are removed, the embryos of such seeds will not grow when they first mature. During the period of dormancy, some physiological changes called after-ripening occur in the embryo before the seed is capable of germination. The seeds of apple, peach, iris and pine belong to this group. In nature, after-ripening occurs in winter and the seeds formed in autumn germinate the coming spring.

5.6 Germination inhibitors

Many species’ seeds fail to germinate even when the embryos are completely developed when the seed is ripe, even though the environmental conditions are excellent. In such seeds, dormancy is caused by the physiological state of the embryo. The embryos of such seeds will not grow when they initially mature, even if the seed covers are removed. Inhibitors may be present in the embryo (example, in Xanthium), endosperm, (example, in Iris) or in the seed coat (example, in Cucurbita). Abscisic acid (ABA) is one of the most commonly detected inhibitors of germination.
6. Conclusion

Seed dormancy is a state in which seeds do not germinate despite the presence of all of the necessary circumstances (temperature, humidity, oxygen, and light), and is caused by hard seed coat impermeability or a lack of supply and activity of the enzymes required for germination. The dormancy of seeds presents a practical problem of considerable economic importance. Plant growers are often interested in securing seed that will germinate soon after it is harvested. Dormancy is a significant limiting factor in the production of many field crops. To overcome dormancy, organic material is subjected to a variety of physical and chemical pretreatments. Some plant species have both physical and internal dormancy, making it difficult to produce high-frequency healthy seedling growth, despite the fact that seed sprouting and the generation of healthy seedlings is a requirement for plant output. The Chapter is intended to present the basic information on the seed dormancy which would be of relevance to the seed growers (farmers) and scientists during seed handling process. Actually, seed dormancy is of great concern to scientists therefore it is a research area of interest. All the viable seeds have capacity to germinate if placed under suitable conditions necessary for germination. But some seeds fail to germinate for sometimes even if placed under the condition favorable for germination.
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