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Understanding Seed Dormancy and Germination

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Seeds are highly important part of living things, without which life would not exist. All of our daily necessities are totally dependent on seed and seed stock, like food and fruits, so also is many of the natural resources that we use as consumers such as, timber, cotton, paper, essential\edible oils, all which started their live as seeds. Basically, a seed consists of a tiny underdeveloped plant, the embryo, which is enclosed by a covering called the seed coat. Germination of seed occurs when the embryo grows into a functioning plant. It involves the rejuvenation of the metabolic pathways that lead to growth and the emergence of the radicle (root) and plumule (shoot). For germination to occur, three basic factors must exist, the seed must be viable, dormancy must be controlled and the proper environmental conditions for germination must be available. Dormancy simply means the inability of seeds to germinate even when the necessary environmental conditions (temperature,

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humidity, oxygen, and light) are favorable for germination. Dormancy is a principal factor restricting the production of crops. Several physical and chemical pretreatments can be applied to the organic material (seeds) to control dormancy. This review discusses the conditions necessary for germination and the fundamental factors necessary for breaking dormancy.

Keywords: Seed; plant; embryo; germination; dormancy.

1. INTRODUCTION

The life cycle of a plant as to its survival as a species begins as seed. The seed is the dispersal part of the plant, which can survive an interval between seed maturity and the formation of the next generation as a seedling after germination [1]. Seeds are important to agriculture and natural ecosystem. Bareke [2] defined seed 'as an embryo, which is an immature diploid sporophyte developing from the zygote, surrounded by nutritive tissue and enveloped by a seed coat'. Germination of plant begins when seeds get wet. When seed sprouts, the embryo grows into a new plant. As seeds imbibe water, the seed coat becomes soft and break. Thereafter, a tiny root (radicle)appears from the seed and grows downward. The shoot (stem) also appears and grow upward after which the first leave appears on the stem and then the seed coat falls off. Seed is crucial in providing nutrients for both animals and humans, and understanding their biology is necessary in improving agricultural management and practices of genetic resources [3].

Seeds have everything necessary for the growth and development of a new plant. In a broad generalization, every seed consists of three essential parts.

- *Embryo:* This is the young multicellular organism before it comes out from the seed to give rise to a new plant(https://www.mycaert.com). It consist of two important parts, the radicle and the plumule which may emerge at different times in different species.
- *Endosperm:*This is the storage tissue which contain the substances which will maintain the embryo during its development prior to and after germination, this is primarily made up of starches. The amount of endosperm varies widely with different kinds of seed.
- *Seed coat:*This consists of one or more protective layers that covers the seed shielding the embryo and endosperm and may also be responsible for the controlling factors thatbegins germination of the seed, in particular, absorbing of moisture and gaseous exchange. This also plays the role of protecting the seed from fungal infestation while in the soil prior to the commencement of germination.

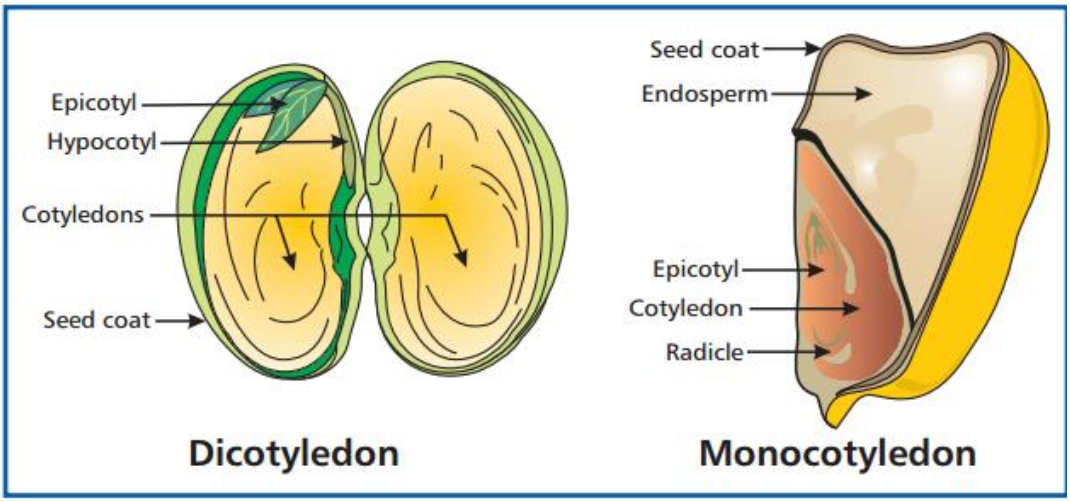

Fig. 1. Seed structure of dicotyledon and monocotyledon
SOURCE: https://www.mycaert.com

2. SEED GERMINATION

Germination of seed is one of the most crucial phases in plant's growth and development as it involves many physiological, morphological and biochemical changes within a seed. By definition, the germination of a seed starts with the uptake of water and is completed when the radicle protrudes from the covering structures [4]. For germination to start, three conditions must be achieved, firstly, the seed must be viable, i.e., the embryo should be functioning and capable of germination. Secondly, the seed should not be dormant and thirdly, the environmental conditions like moisture, temperature, air and light must be available in appropriate amount [5]. Different seeds have different germination challenges, it is therefore important for growers to learn about the species he /she intends to grow. Knowing the habitat, ecology and life history of the seed are things that should be put into consideration by a grower. Germination is the crucial and final event in the life of a seed. The visible sign that germination is complete is usually the penetration of the embryo structure by the radicle; the result is often called visible germination. Germination is a crucial developmental transition since it precedes the establishment of the seedling. Normal germination requires imbibition with water and first involves testa rupture, which is probably the result of micropylar endosperm cell expansion, followed by concomitant endosperm rupture and radicle protrusion out of the testa [6,7,8,9].Seeds need certain condition for normal germination and the most important are substrata, moisture, oxygen, temperature, and light.

- *Substratum*: A suitable substrata for seed germination include paper toweling, blotter paper, filter paper, cotton, sawdust, sand or soil [10].
- *Moisture:* This is required in order to start the mechanism of germination. The seeds are planted on a moist substratum. Mature seeds are often extremely dry and need to take in significant amounts of water, relative to the seeds dry weight, before cellular metabolism, to resume their growth [11]. When seed absorb water, hydrolytic enzymes are activated that break down these stored food resources into metabolically useful chemicals, allowing the cells of the embryo to divide and grow. Seed coat burst so the seedling can emerge from the seed. Excess moisture can stop germination by restricting respiration which can cause abnormal seedling. When this happens, such seedling will not develop chlorophyll, the root will lack root hair and eventually will die.
- *Oxygen:* This is essential during germination for respiration and other physiological activities. A few water inhabiting plants germinate best under full or partly anaerobic condition. Some seeds have impermeable seed coats that prevent oxygen from entering the seeds; it is called as seed dormancy.
- *Temperature:* Suitable temperature is an important factor for proper seed germination. Some seeds grow best under temperatures slightly higher than room temperature, some germinate just above freezing point and others require an alternating temperature between warm and cold. Some seeds require exposure to cold temperature to break dormancy so they can germinate.

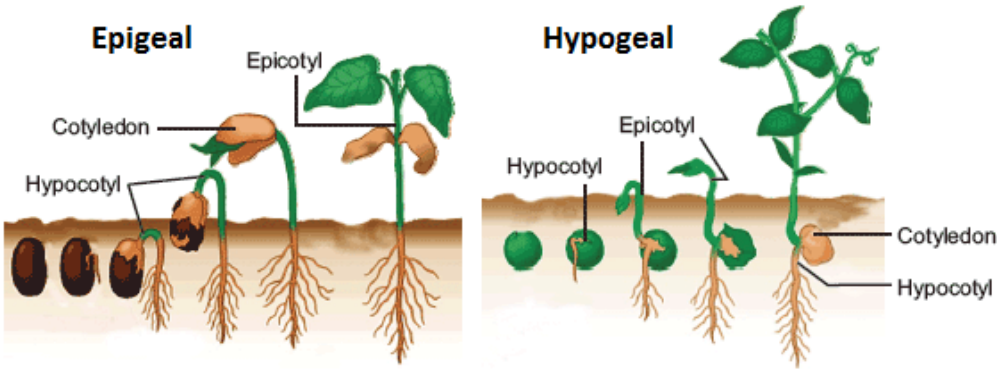

Fig. 2. Epigeal andHypogeal germination

SOURCE:https://www.plantscience4u.com/2014/08/types-of-seed-germination-epigeal-and.html

- *Light or darkness:* Light acts as an environmental trigger for germination in seeds. Most seeds are not affected by light or darkness. A few seeds prefer to germinate in darkness, other are indifferent and some need light. Many seeds, including species found in forest settings will not germinate until they receive sufficient light for the seedlings to grow.

These important factors must exist before germination can take place; seed must be viable, dormancy must be eliminated to allow proper seed germination, proper environmental conditions must be present for germination to take place.

2.1 Types of Seed Germination

- ***Epigeal germination*: This is a type of germination whereby the cotyledon comes above the soil surface along with the shoot during germination, it is also called**epigeous germination. This is usually due to excessive growth and curved shape of the hypocotyl. Because of this change in shape, it allows the cotyledon to appear on top of the soil. After the emergence of the cotyledon at the top of the soil, the hypocotyl stretches out which results to the seed coat falling off and the cotyledon turns green overtime. When the plant eventually matures giving rise to green leaves, the cotyledon falls off overtime. The principal function of cotyledons in Epigeal germination is storage of food. They also undergo photosynthesis and produce food for the development of the embryo. This type of germination is common in beans, onions, castor e.t.c.
- *Hypogeal Germination*: This is the type of germination whereby the epicotyl elongates and the hypocotyl does not raise the cotyledon above the soil surface. The cotelydon remains below the soil due to the elongation of the epicotyl, this germination is also called hypogeous germination. The cotyledons do not play any role in photosynthesis.

3. DORMANCY

Because it is the function of seed to develop into a new plant, it may seem peculiar that dormancy, an intrinsic block to germination, exists. When this exist, seeds will not germinate freely even in seemingly favorable conditions. Almost all the metabolic activities that are known to occur before the completion of germination of non-dormant seeds also occur in imbibed dormant seed. Hence, a dormant seed may achieve almost all of the metabolic steps required to complete germination, yet for some unknown reason, the radicle fails to elongate. Finch-Savage and Leubner–Metzger [12], regarded seed dormancy as the failure of an intact viable seed to complete germination under favorable conditions. The agricos described seed dormancy as the failure of fully developed, mature, viable seed to germinate even under favorable physical conditions (moisture and temperature).It is has been discovered that seeds of some fruit plants germinate immediately after extraction from the fruit under favorable environmental conditions. However, in others germination does not take place even under favorable conditions. This phenomenon is called as 'dormancy' [13]. The conditions necessary to allow seeds to "break" dormancy and germinate can be highly variable among species, within a species, or among seed sources of the same species [14]. The habit or type of seed dormancy determines the ecological niche of its germination and propagation, which is substantially related to factors of climate, humidity, soil, light, nutrients and biological and abiotic stresses [15].

The timing of seed germination depends on a seedling's seasonal exposure to potentially lethal environmental factors, and thus has strong fitness consequences [16,17]. However, for much of the world's flora the particular mechanisms that regulate seasonal emergence patterns are unknown [18]. These mechanisms may involve a combination of environmental germination requirements and seed dormancy.

Seed dormancy mechanisms are regarded as the principle means by which seeds can control the timing of germination and thus are expected to be under strong selective pressure. Dormant seeds sense and respond to their environment in order to avoid a germination response to temperature or rainfall that would not support subsequent seedling growth [19]. Dormancy classification is based on the developmental state of the embryo at the time of seed dispersal, physical traits of the seed, and physiological responses of seeds to environ- mental stimuli [20]. Dormancy breaking occurs when a physically dormant seed receives an environmental signal, such as temperature

fluctuations, wet heat, dry heat, or alternate wet–dry conditions [21].

Dormancy classification is based on the developmental state of the embryo at the time of seed dispersal, physical traits of the seed, and physiological responses of seeds to environmental stimuli [20]. Dormancy is classified into two stages; Primary dormancy and Secondary dormancy.

3.1 Primary Dormancy

Primary seed dormancy is the dormancy that develops during seed development in the mother plant [9]. Primary seed dormancy is a fundamental property of freshly produced seeds. The trait is functionally defined, a germination test is needed to assess whether a dry mature seed shows primary dormancy or not [22]. Primary dormancy is released during dry after ripening when seeds gradually acquire the capacity to germinate when exposed to favorable germination conditions and therefore become non-dormant [23]. Sometimes, dormancy is caused by inhibiting chemicals inside the seed. Primary dormancy isclassified into exogenous dormancy (physical, chemical, and mechanical), endogenous dormancy (morphological and physiological) and combinational (morphological and exo-endodormancy).

3.1.1 Exogenous dormancy

- *Physical dormancy*: Seeds with physical dormancy possess hard seed coats that do not allow the seed to absorb water. It is due to impermeability of seed coat to water. Sometimes, dormancy is caused by inhibiting chemicals inside the seed. Seeds with seed coat dormancy can remain on/in the ground without germinating until the seed coat allows water and oxygen to enter the seed or eliminate the inhibiting chemicals. Seeds with physical dormancy can remain non germinated and viable in soil for many years, thus allowing them to form a soil seed bank [24].
- *Chemical dormancy*: This is due to the presence of chemical inhibitors in the outer coverings of many fruits and seeds which may be removed off the tissues by washing or soaking of the seeds or by other means. Some of the substances causing inhibition are various phenols, coumarin and abscisic acid. These substances can strongly inhibit seed germination.
- *Mechanical dormancy*: This happens when the hard seed coat restrict the radicle from expanding during germination, resulting in dormancy of seed. The seed coat structure of some seeds like shells of walnut, stones of olive and pits of stone fruits are too hard to allow proper expanding of the embryo during germination. Germination can only occur in such seed only if the seed coats are softened either by subjecting the seed to a warm environment and moist condition or by microbial activity.

3.1.2 Endogenous dormancy

- *Morphological dormancy*: In seeds with morphological dormancy, the embryo is small (underdeveloped) and differentiated, i.e. cotyledon(s) and hypocotyl radicle can be distinguished [24]. Embryos in seeds with morphological dormancy are not physiologically dormant [25] and do not require a dormancy-breaking pretreatment per se in order to germinate; thus, they simply need time to grow to full size and then germinate (radicle protrusion).

- *Physiological dormancy*: This prevents the growth of embryo and germination of seeds until chemical changes occur. Physiological dormancy is broken when inhibiting chemicals are broken down or are no longer produced by the seed. Physiological conditions giving rise to internal dormancy surface from the presence of germination inhibitors inside the seed. The cause of delay of these inhibitors should be terminated in order for germination to begin and this done by using germination-promoting substances such as gibberellic acid (GA3) and potassium nitrate (KNO_3) and the most common inhibitor is abscisic acid (ABA) [26].

3.1.3 Combinational dormancy

- *exo-endodormancy:* Combination of exo and endogenous dormancy.

4. SECONDARY DORMANCY

Secondary dormancy has been less extensively studied than primary dormancy. Although both primary and secondary dormancy appear to

share common underlying germination control mechanisms, notably the involvement of the phytohormones gibberellic acid (GA) and abscisic acid (ABA) [9], whether they are similar at the molecular level remains poorly understood [27,28]. Secondary dormancy is known to be present in non-deep physiological dormancy and is a denomination used with seeds that lost primary dormancy to describe their behavior when exposed, notably in a prolonged manner, to environmental signals that are unfavorable for germination such as darkness or low temperatures [29]. Even after primary dormancy is lost, seeds can acquire secondary dormancy if conditions are still unfavorable for germination, and dormancy cycling can occur under natural conditions [30]. Secondary dormancy can be induced by specific environmental factors, such as moisture and temperature, which vary seasonally.

- *Thermo dormancy:* High temperature induced dormancy.
- *Conditional dormancy:* This result as a change in ability to germinate relating to time of the year.

4.1 Advantages of Dormancy

- As a result of their impermeable seed coat, dormant seed can stand a high rate of survival during cold or hot temperature and even under drought condition that increases their resistance in a good way.
- It allows storage of seed for use by animals and man and also helpful in creation of a seed bank.
- Dormancy help seeds to remain alive in the soil for several years, providing constant source for the development of new plants even when all matured plants are dead due to inevitable accident.
- It helps in the proper dispersal of seeds to far places through the unfavorable environment.

4.2 Disadvantages of Dormancy

- It disallows quick and uniform seedling growth thereby causing problem in maintaining the plant population.
- It can interfere with the seed testing procedures causing problems for the seed analyst.
- Weeds with dormancy nature are difficult to eliminate.
- Weed seed can survive in the soil for many years.

5. PLANT HORMONE INTERACTION

Plant hormones such as abscisic acid (ABA), gibberellins (GA), auxin (IAA), cytokinins and brassinosteriods are biochemical substance that controls many physiological and biochemical processes in plants. These substances are made by plants and soil organism (Santner *et al.,* 2009, Jiminez, 2005).

5.1 Abscisic Acid (ABA)

Abscisic acid (ABA) and gibberellins (GA) are the major plant hormone that controls seed dormancy and germination [31,32], (Shu *et al.,* 2016). While ABA positively affects stomatal activity, seed dormancy and activities of the plant under abiotic and biotic pressures, it however affects seed germination process unfavorably (Popko *et al.,* 2010). Seeds pass through changes in both ABA content and sensitivity during seed development and germination in response to external and internal signals [33].There are substantial proofs that ABA is an important positive regulator of both the induction of dormancy and the maintenance of the dormant state in imbibed seeds following shedding [12]. Miransari and Smith (2013) stated that primary dormancy is caused during seed development because of the effect of abscisic acid. ABA is considered a major inducer and protector of seed dormancy [34]. Seeds with usually ABA deficient mutants germinate quickly than the wild-type [35] and chromosomal plants showing the ABA biosynthesis gene sustain deep seed dormancy [36, 37].

5.2 Gibberellin (GA)

GA are able to trigger dormant seeds, although hormone does not control seed dormancy (Miransari and Smith, 2009). Likewise, GA boost seed germination by inhibiting ABA activity. This is done by the activation of catabolizing enzymes and preventing related biosynthesis pathways which decreases the amount of ABA synthesis (Atia *et al.,* 2019).GA hinders ABA effect and promote seed germination [38].

5.3 Auxin (IAA)

Auxin is a plant hormone that plays an important role in balancing growth and development, formation of vascular tissues and cell cycling

(Miransari and Smith, 2013). Auxin is involved in almost all areas of plant development and it respond to a multitude of environmental signals [39].

6. CONCLUSION

A typical seed requires proper temperature, moisture, air, and light conditions to germinate but not all seed tend to have the same germination requirements, therefore, it is highly important to know what each seed type needs. Knowing what seeds need before you get started will help achieve a greater germination percentage and seedlings growth. A seed may be viable and still will not germinate and grow. This can be affected either by external or internal conditions. External condition that causes germination problems can often be averted and the most common external conditions are soil related. Internal conditions could be that the embryo has not reached its matured stage to encourage germination due to chemical inhibition or the seed coat is too hard that it disallows water absorption and oxygen preventing it to resume growth. Seed germination is a crucial process that influences plant yield and quality. Therefore, understanding seed dormancy and germination is of a great importance for the improvement of plant yield. The conditions necessary for germination and the fundamental factors necessary for breaking dormancy have been stated in this review which are ultimately important to be considered by agriculture and forest producers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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