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Germination Physiology and Optimum Values in Cereals

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A B S T R A C T

Seed germination is the first important stage of plant growth. It is also a critical step for plant productivity. The morphological changes during germination, followed by physiological and biochemical changes, are strongly correlated with vegetative growth, which affects seedling survival and ultimately yields and quality. Seed germination is the process by which a seedling develops from a seed. It is described as the process by which a seed maintains its viability until it reaches optimum conditions, at which point germination is initiated by water absorption through the seed coat. Optimum conditions are generally different for each species. Germination physiology in cereals is an important area of study that controls the growth and development of the plant throughout its life from the seedling stage and has many implications. At the same time, germination stages in cereals are effective in determining seedling persistence and also affect the chemical composition of the seedling. Healthy seedlings can only be obtained through a healthy germination process. This study aims to provide information on seed germination metabolism, germination physiology of cereals and optimum germination values.

1. INTRODUCTION

Seed germination is a vital process for all plants. It is also the most important step in agricultural production. In agricultural production practices, it is desirable for seeds to germinate uniformly, as this allows simultaneous cultural practices for product quality. It also helps to ensure that competition between plants is at an equal level. For this reason, it is important to study seed germination physiology in detail and to improve germination parameters, especially for crops.

Germination physiology in cereals is an important basic science with many practical implications, ranging from grain quality assessment to storage and preservation. Germination is the metabolic process that can lead to reduced nutrient content and increased seedling susceptibility in cereals (Rodriguez et al., 2015).

Germination physiology involves highly complex procedures. Endogenous and exogenous factors play an important role in the germination of a seed. Some of the endogenous factors are phytohormones and endosperm degradation. Exogenous factors are environmental influences such as light and temperature (Carrera-Castaño et al., 2020). Seed germination is the first and most important step the plant must take to meet its basic needs. Many biochemical events take place during this important step. It is therefore essential that the seed is (optimally) compatible with internal and external factors during germination.

The germination of the seed depends primarily on the completion of its physiological development and its viability. If it has completed its physiological development and is found to be viable after the relevant viability tests are carried out, the next stage is the dormancy phase of the seed (Yılmaz, 2016). Dormancy can be observed in the seed for many different reasons and this situation should be corrected first (Roman et al., 2022). Otherwise, the seed may not germinate even under optimal conditions. A healthy seed, with or without dormancy, should be in optimal environmental conditions for germination (Notarnicola et al., 2023). Optimum germination conditions may vary from one plant species to another. It is therefore necessary to provide optimum germination conditions specific to each plant species or variety.

Germination literally begins when the seed absorbs water and culminates in the elongation and emergence of the embryo axis (Hernández Cortés, 2022). It is well known that physiological events in living cells depend on the presence of water. Germination is not possible unless water is absorbed from the environment (Küpe, 2023). The absorption of water leads to the initiation of a series of physical and chemical events in the seed and thus to germination. Nutrients stored in the embryo or endosperm of the seed begin to move in the presence of water (Muhie, 2019). A significant amount of water enters the seed in contact with water through swelling and osmosis (Zengin & Sarıbaş, 2020). This is because the osmotic or swelling pressure in the seed is exceptionally high. Therefore, the seed often does not need to be in direct contact to absorb water. In order to germinate, the seed can also absorb the water it needs from the humidity of the air (Sumiahadi, 2020). Germination in cereals is the process by which the ovary wall of the seed dissolves and the rootlet or seed root and shoot emerge. The seed coat expands as it releases stored food reserves from the endosperm. In this context, germination of a grain can be explained as the production of an active form of grain called a seed, and germination involves a wide range of biological processes. Among them, the most prominent common feature is the change in the appearance and chemical structure (nutritional values, antinutritional factors, toxic components) of the seed (Mohammed, 2016). Based on the given information, this study attempted to reveal germination physiology and optimum germination values of cereals from different literature.

1.1. Germination Physiology in Cereals

All living things benefit directly or indirectly from cereals, while maintaining their vital activities. While cereal grains are evaluated in terms of carbohydrate, protein and fat (Figure 1.), they are also at the forefront in terms of antioxidant substances in their composition. Oxygen is the basic element found in units such as carbohydrates, proteins and fats, which form the basic structure for vital activities. Cereals are divided into two groups in terms of climatic requirements: warm climate cereals and cool climate cereals. The cool climate cereals are wheat, barley, rye and oats, while the warm climate cereals are maize, paddy, birdseed and sorghum (millet) (Zülkadir, 2022). When the seed morphology of these cereals is examined, it is found that they generally consist of micropyle, radicle, coleoptile, scutellum, pericarp, seed coat, aleurone, endosperm and brush (Figure 2). Although it is the most stored food component, it is approximately 70-80% starch, about 15% protein, and less than 5% lipids, minerals and vitamins (Ali & Elozeiri, 2017) (Figure 1).

Germination in cereals begins with the uptake of water by the seed coat. Contact with water or absorption of moisture from the air softens the seed coat. While water uptake is initially rapid, it slows over the next 5 hours. In addition, the low water content in the seed tissue leads to rapid water uptake in the initial period (Rathjen et al., 2009). As the seed absorbs water, it also absorbs water-soluble substances.

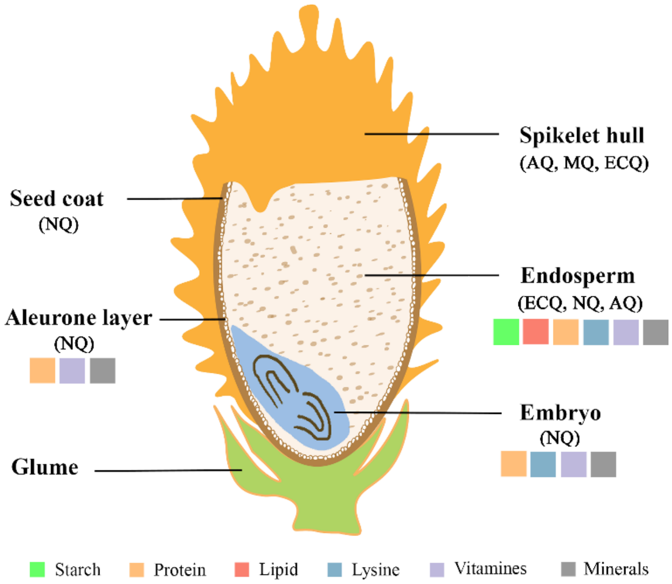

Figure 1. Overview of the main structure and components based on a longitudinal section of a mature rice seed (Li et al., 2022)

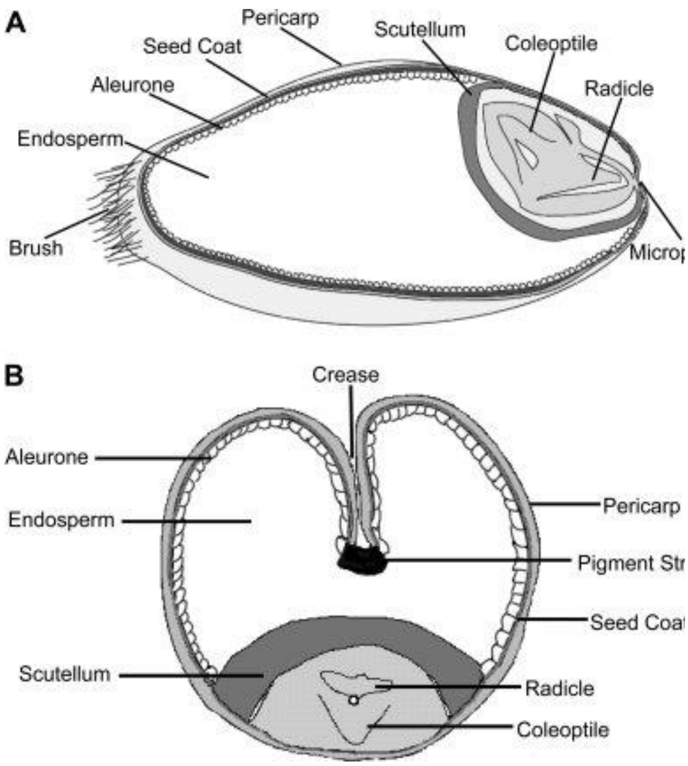

Figure 2. Main structure of wheat seed with longitudinal (A) and transverse (B) sections (Rathjen et al., 2019)

After water uptake, the carbohydrates, proteins, lipids and phosphates stored in the seed act as energy sources and carbon skeletons. In order for these storage substances to be taken up by the embryo, they are hydrolysed into a usable form (Figure 4.). In this way, the metabolic pathway activates hydrolytic enzymes. This is accompanied by a high level of oxygen consumption. In cereals, most hydrolytic enzymes are produced in the aleurone or scutellum in response to germination signals (Ali & Elozeiri, 2017). During germination, starch reserves are hydrolysed into simple sugars (Figure 3.), oligosaccharides and polysaccharides by α-amylase, nitrogen-containing fractions into oligopeptides and amino acids by proteolytic enzymes, and triacylglycerols into fatty acids by lipase. While the amount of anti-nutritional factors (phytate, trypsin inhibitor, tannin, etc.) decreases, the amount of bioactive components (phenolic acids, flavonoids, GABA, etc.), which have many benefits for human health, increases significantly. The increase in bioactive compounds increases the antioxidant capacity of the grain. This increases the functionality of cereal sprouts (Şenlik & Alkan, 2021). Seed imbibition triggers many biochemical and cellular processes associated with germination, including reactivation of metabolism, resumption of cellular respiration and mitochondrial biogenesis, translation and/or degradation of stored mRNAs, DNA repair, transcription and translation of new mRNAs. These processes are followed by the accumulation of ROS (mainly H_2O_2), which is the result of a marked increase in intracellular and extracellular production in the early stages (El-Maarouf-Bouteau & Bailly, 2008; Kubala et al., 2015).

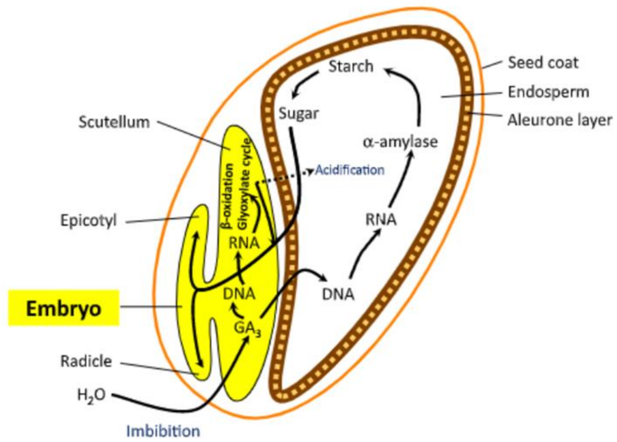

Figure 3. Metabolic processes in embryo and endosperm during germination of barley (Ma et al., 2017)

According to Majeed et al. (2012), some of the physiology of germination in cereals include: a) water uptake and its effect on water-soluble substances and growth processes, b) the role of hydrogen peroxide in enzyme activation, c) the effect of temperature on various metabolic activities, and d) micronutrients derived from reserves (Majeed et al., 2012). Cereal germination is closely related to the content and structure of the embryo. Germinating cereal proteins contribute to the functionality of cereal products, such as improving nutritional value through bioavailability or functional properties (Majeed et al., 2012). Germination is the first stage of development that takes place in the cereal grain. At this stage, the processes of water uptake, loss and entry through the grain embryo that cause changes in the volume and morphology of each organ (i.e., endosperm, seed coat and aleurone layer) are interrelated to initiate the process of emergence from dormancy (Kumar & Kalita, 2017). In cereals, it is estimated that more than 50% of the energy invested in growth is used to break down the hard seed coat, which is usually multilayered. After germination, the seedling emerges from the seed coat, roots grow from the embryo and leaves develop from the embryonic leaf primordia (González Carretero et al., 2017).

1.2. Optimum Growth Conditions of Cereals Germination Values

Cereals in cool climates can germinate at temperatures as low as 1-4°C (Balşen 2022). They require a total temperature of 1750-2250°C during a growing season (Taner & Bayram, 2005). For this reason, cool climate cereals are generally grown in the winter belt. Wheat and barley are cool climate cereals. Cool climate cereals, which are mostly grown successfully in temperate and cold climates, cannot be grown in tropical climates where it is very hot and rainfall exceeds 1500 mm (Taner & Bayram, 2005).

Cold climate grasses show optimal development in the range of 15-21°C. Originating from the cooler regions of Europe and Asia, the seeds of these plants are highly resistant to cold and are used in areas with continental climates (Kıldış, 2021).

Some wheat genotypes require a certain amount of chilling and light for emergence and germination. Wheat genotypes that do not require chilling or require very little chilling for emergence are called "summer wheats" and those that require chilling are called "winter wheats". The need for chilling is recognized as a mechanism to protect wheat from cold (Okhan, 2022). For this reason, winter wheat is sown in autumn in our country.

The optimum growth temperature of wheat growing areas is 25 degrees Celsius, while the minimum and maximum growth temperatures are between 3-4˚C and 30-32˚C, respectively. In our country, wheat cultivation is mostly carried out in arid and semi-arid areas depending on rainfall, and exposure to dry and high temperatures, especially during the grain growth period, causes a significant decrease in yield (Sayılğan, 2016).

The lowest germination and photosynthetic temperatures of cool-climate cereals, including wheat, barley, oats, rye, triticale and spelt, are 1-4°C and 5-7°C, respectively. They can be grown in regions where the total temperature during the growing season is 1750-2250°C, which can meet the vernalization requirement between germination and stem emergence, with low temperature, cloudy and wet days in the vegetative period and abundant sunny days in the generative period. Cool-climate cereals, which are the most adaptable group of crops to different climatic and soil conditions, can be grown in almost all regions of our country. In our coastal regions, they are generally cultivated under higher rainfall or irrigated conditions, while in our other geographical regions and inland regions, they are mostly cultivated under dry conditions (Kün, 2004).

The responses of cereal germination to environmental factors are important in understanding the limits under which a crop can grow and produce maximum yield. Knowledge of grain germination is of primary importance not only to seed technologists, but also to agronomists, plant physiologists, plant biologists and soil scientists involved in field management (Fowler, 2003).

For warm-climate cereals (such as maize and rice), temperature requirements are quite high. The minimum germination temperature is 9-12°C and the optimum germination temperature is 18-20°C. Low temperatures after emergence will arrest growth, while conditions that prolong the initial growing season will slow growth, facilitate disease infection and reduce yield. It is very important to decide on the sowing date according to the region, taking these values into account. The average daily temperature during the growing season should be above 20°C. Optimum growth temperatures are between 25 and 30°C. Early sowing of the main crop causes cold damage during germination and initial development. The desired early sowing of the second crop depends on the drainage of the field by the preceding crop, while late sowing results in high moisture content in the crop and cold damage in the autumn. During flowering, excessively hot and dry weather damages the inflorescences and disrupts fertilization. Plant reproductive organs are severely damaged by temperatures above 45°C during the flowering period. This problem is particularly important in the production areas of south-east Anatolia and the Mediterranean coast of our country. Variety and sowing time should be chosen correctly so that the flowering period does not coincide with the extremely hot period. The opposite practice increases the rate of infertile spikelets in paddy. Similarly, grain attachment in maize cobs is disturbed and gaps increase (Kün, 2004).

2. CONCLUSION

Germination has been described as a process involving complex interactions between a number of factors, including genotype, environment and physiology. It is believed that the knowledge gained from research will lead to advances in breeding and improve the yield and quality of cereals.

Germination is one of the most important steps in crop production. It involves the physiological changes of seeds in water and darkness, including biochemical, morphological and physiological changes that lead to the production of roots and shoots.

By understanding the physiology of cereal germination, growers can improve the quality of their seed and increase yields.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

The authors declare that they have contributed equally to the manuscript.

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

Data availability is not applicable to this article as no new data were created or analysed in this study.

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