Wollo University
College of Agriculture, Department of Plant Science
Course name: seed science and technology note

CHAPTER 1. INTRODUCTION

1.1 Definition

What is seed?

In broad sense, seed is any plant part which is utilized for commercial multiplication of a crop

- ✓ To ***a botanist***, a "seed" is a specialized plant structure, complete with a tiny embryo, which is capable of growing into a new plant (i.e. seed is a fertilized (matured) ovule)

❖ The term **seed system** represents the entire complex organization, individual and institution associated with the development, multiplication, processing, storage, distribution and marketing of seed in any country

Seed technology- is a science dealing with the methods of improving the genetic and physical characteristics of seed.

- ➢ In its narrow sense, seed technology comprises techniques of seed production, seed processing, seed storage, seed testing and certification, seed marketing and distribution and the related research on these aspects.
- ➢ In its broad sense, seed technology includes activities such as development of superior crops and their varieties through breeding, their evaluation and release, seed production, handling, processing, storage, testing, certification, quality control, marketing and distribution.
- ✓ It also includes research into seed growth and development, seed physiology, seed dormancy and germination, seed viability and longevity, seed pathology and microbiology and seed enhancement based on modern botanical and agricultural sciences

Goals of Seed technology

The followings are the major goals of seed technology

1. Rapid multiplication- increases in agricultural production through quickest possible spread of new varieties developed by the plant breeders

2. Timely supply- the improved speed of new varieties must be made available with in time to increase agricultural production

3. Assured high quality of seed –to obtain the expected dividends from the use of good seed for planting purpose.

4. Reasonable price- the cost of high quality seed should be used within reach of the average farmers.

5. The development of seed program- is one of the most important steps in agricultural development.

1.2 Seed structure

Angiosperm seeds/true seeds consist of three genetically different components.

a. **Embryo:** is developed from a zygote. The embryo is surrounded by the endosperm, nutritive tissue.

Structural feature of the embryo consists

- ✓ Cotyledons: extensions of the embryo
- ✓ Epicotyle: top of embryo which becomes **shoot tip**
- ✓ Hypocotyle: below epicotyl, it becomes the **shoot**
- ✓ Plumule: embryonic shoot; first true **leaves** attached to epicotyl
- ✓ Radicle: below hypocotyl, it becomes **root**

b. **Endosperm:** formed by the fusion of two polar nuclei with the second spermatic nuclei.

- ✓ It is used as a food by the embryo and seedling during development of the seed and germination. It is rich in oil, protein and starch.

✓ On the basis of presence or absence of endosperm seeds are categorized in to two.

I. Albuminous (endospermic seeds): endosperm present

E.g. Cereals….maize, wheat, rice

ii. Exalbuminous (nonendospermic seeds): endosperm absent Eg. Legumes bean, pea etc

c. **Seed coat:** which is outer covering of the seed developed from the integuments.

✓ Seed coat is a protective coat made up of two layers, testa (outer thick layer) and tegmen (inner thin membrane) present as an envelope to protect the embryo and endosperm from desiccation, mechanical injury, effect of environmental fluctuations and damage due to insects and microorganisms.

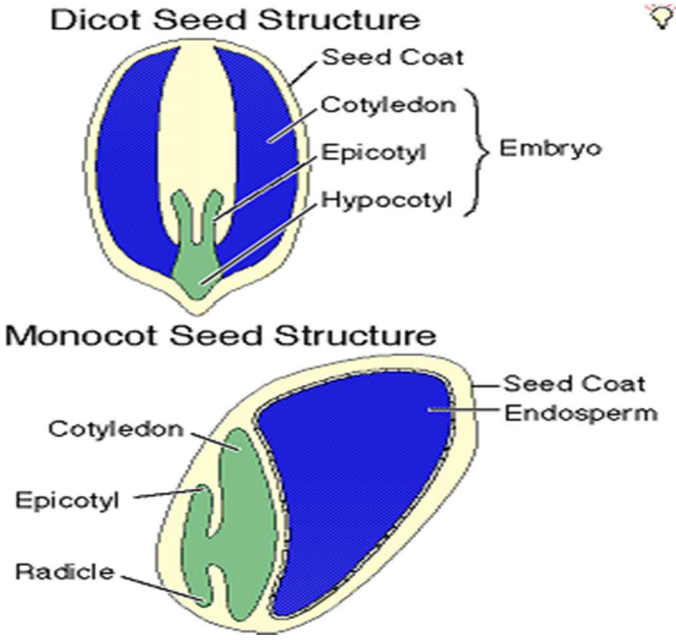


Figure 1: The major botanical structures of dicot and monocot seeds

1.3. Seed as a basic input in agriculture

From the ancient time, the seed has been an important input for agriculture. Many plant species have been domesticated far away, from the region of their origin, by seeds i.e. planting material which produces the next generation. Hundred years ago farmers in general did not know the basic difference between seed and food grain. It became a tradition to save some grains or purchase some grains or exchange some grains for planting the next crop. Even now people in interior villages do the same. It was after the discovery and establishment of the "Mendel's Laws of Inheritance" that the scientists began to understand that all inputs in agriculture such as chemical fertilizers, irrigation, climatic conditions etc. give higher returns only when good quality seeds are sown.

- ***Seed is a carrier of new technologies***
- ***Seed is a basic tool for secured food supply***
- ***Seed is the principal means to secure crop yields in less favorable production areas***
- ***Seed is a medium for rapid rehabilitation of agriculture in times of natural disaster.***

CHAPTER 2: SEED FORMATION AND DEVELOPMENT

2.1. Seed Formation: Seeds in angiosperms are derived from flowers in a sequential process involving flower bud induction and initiation, flower differentiation and development, pollination and fertilization, seed formation, growth and development of the seed. Seed formation begins with the combination of a male and female gamete, a process known as fertilization. Fertilization can occur when both male and female gametophytes are fully mature. This usually occurs in a dual fusion process known as double fertilization. In angiosperms, the pollen grains on transfer to the stigma, germinate to produce the pollen tube, which penetrates through the style, enters the ovule through the micropilar opening and discharges two sperm nuclei into the embryo sac. One sperm nucleus unites with an egg nucleus to form a zygote, which eventually becomes the new plant. It further develops into an **embryo**. The other sperm nucleus unites with two polar nuclei in the embryo sac to form an **endosperm**, which serves as a storage organ for developing seed. Thus, the whole process involves two or double fertilization events. The fertilization process is completed within one or two days of pollination and is followed by withering of corolla, stamen and stigma. The process of fertilization is very important because it not only results in the formation of a seed but also dictates the level of genetic diversity present in the zygote.

Fertilization in angiosperms occurs either by self or cross fertilization.

a. **Self-Fertilization**: occurs when pollen from the anther of a flower is transferred to the stigma of the same flower or to the stigma of another flower on the same plant.
b. **Cross Fertilization**: occurs when pollen grains are transferred from anther of a flower on one plant to the stigma of a flower on another plant of the same species. In most agricultural crops cross fertilization occurs by two principal methods. Wind (anemophily) and insect (entomophily). Unlike self-fertilization, where progeny are genetically similar, cross fertilization results in progeny that are more dissimilar.

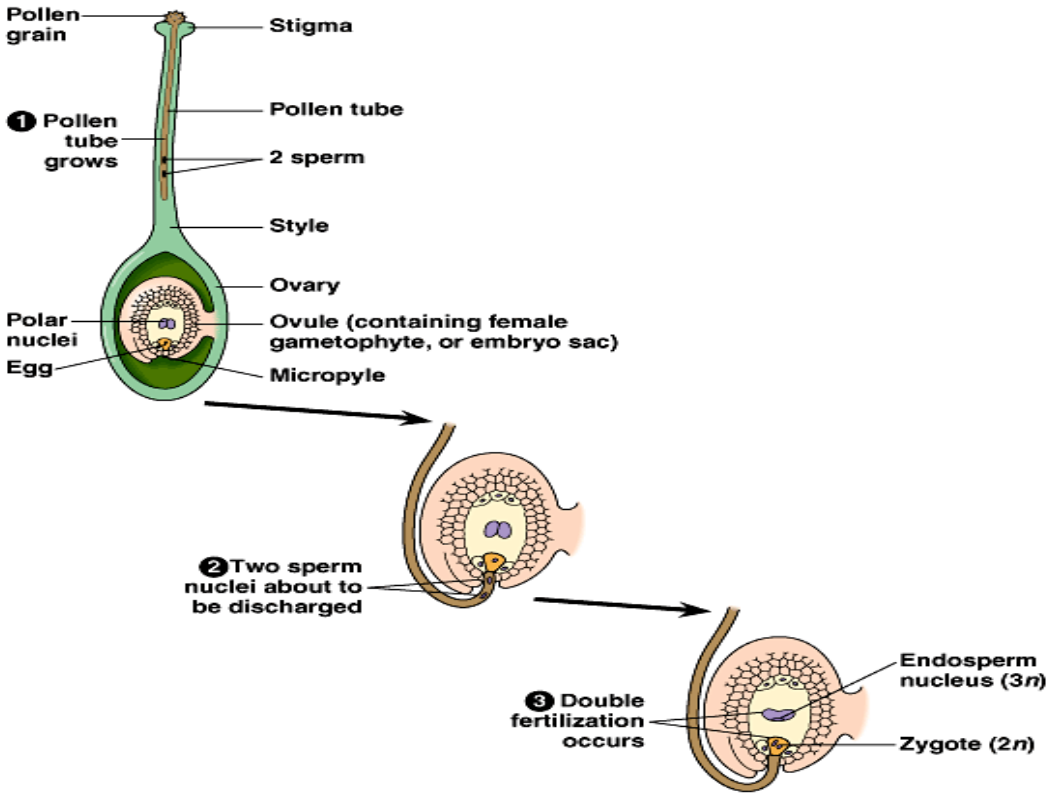


Figure 2: A sequential process of Seed formation in flowering plants

2.2. Seed Development: after fertilization development of the seed starts in **ovule**. In spite of initial similarities, the seed develops according to the genetic specifications for each species, which are coded in the nucleus (chromosomes) of each cell

Embryo development: after the polar nuclei are fertilized, fertilization of the egg cell occurs to form the zygote, which ultimately develops into the embryo. Initially, cell division in the zygote does not begin until at least a small amount of endosperm has formed. The few cell stage of the embryo is known as proembryo.

Proembryo development of dicot seeds undergoes four stages:

✓ The globular stage is characterized by numerous mitotic divisions and produce apparently undifferentiated cells.

✓ The heart stage is marked by the formation of two lateral, multicellular extensions that become the cotyledons.

✓ The torpedo stage is so named because the embryonic axis is initiated and elongates in conjunction with the developing cotyledons to produce a proembryo that resembles a torpedo. By this stage vascular differentiation is apparent. Further development leads to the formation of epicotyle.

✓ ***Monocots also undergo the development of a globular embryonic stage. However, since only one cotyledon is formed, they do not exhibit the remaining stages characteristic of dicots.***
The cotyledons of many dicot seeds vary in shape. Endospermic seeds tend to have thin, delicate, leaf like cotyledons while non-endospermic seeds such as pea and bean possess cotyledons that are bulky and represent as much as 90% of the seed's dry weight

Endosperm development: endosperm development is initiated by the fusion of one sperm nucleus with two polar nuclei resulting in a triploid (3n) endosperm. This process occurs in most angiosperms. The endosperm nuclei divide initially without the formation of cell wall. After considerable nuclear divisions, cell wall formation begins at the periphery of the embryo sac. The outer most layer of the endosperm develops into the aleurone layer, which possesses high quantity of proteins and has an important role in the synthesis of enzymes that degrade the endosperm during germination.

✓ The endosperm serves as the principal nutritive support for the embryo of many species, especially monocotyledons during both seed development and germination

In most dicotyledonous species the endosperm is formed but is almost completely consumed during seed development so that the mature seed is composed almost entirely of embryo

Monocotyledonous endosperms usually reach their maximum morphological development at physiological maturity and remain to comprise a major part of the seed.

Morphological development: morphological development of the seed occurs concurrently with cytological, chemical and weight changes.

a. **Change in weight**: after sexual fusion, the developing seed begins to increase in weight as a result of nutrient and water intake associated with rapidly accelerating cell division and elongation. In monocots, the developing endosperm accounts for most of the weight increase, with the testa-pericarp weighing somewhat less and the embryo's weight almost negligible. The developing seed undergoes a sharp increase in dry weight until about 35-40 days after fertilization. Immediately after fertilization, most of the dry weight is in the seed coat; however after about 8 days, its weight is surpassed by the endosperm, which later becomes the major seed component

b. **Chemical changes**: immediately after fertilization seed development begins and the seed becomes the primary recipient (sink) of the assimilates from the plant. In monocotyledonous seeds, the major carbohydrate in the endosperm and the entire seed is starch. The carbohydrate content increases rapidly as the endosperm develops, at the expense of testa-pericarp tissue, where it decreases slightly. Sucrose and reducing sugar levels, initially high in the young endosperm, decrease rapidly as the starch content rises. However both sucrose and reducing sugars increase in the testa-pericarp during early seed development and then decrease rather sharply as the seed matures. Seed storage proteins (prolamins and globulins/glutelins) increase rapidly in seed development and reach its maximum content in endosperm and minimum in the

embryo, and aleurone (outer most layer of endosperm) at seed maturity. Other seed chemical compositions such as lipids (faty acids and oils) and inorganic substances (water, minerals, vitamins etc.) increase on seed development and mainly stored in the endosperm

2.3. Phases of seed development

Seed development from fertilization to the mature seed, can be divided in to three phases.

Phase I (development of seed structure): Pollination and fertilization initiates phase 1 and is followed by a period of rapid cell division until all seed structures are formed. 80% of the seed growth occurs at this phase. It is characterized by numerous cell divisions and elongation and dramatic increases in seed weight as nutrition is supplied through the funiculus by the parent plant.

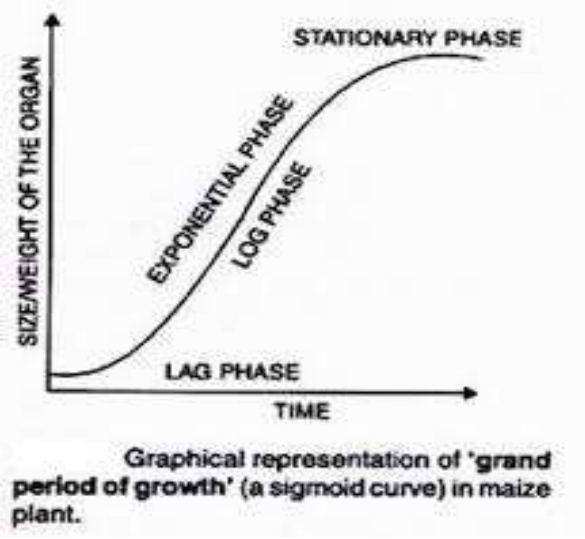
Phase II (linear phase of seed development): is when the seed accumulates reserve materials that give it economic value. The linear phase of seed development begins at the end of cell division and phase I. Cell number is now fixed at its maximum and the rate of dry matter accumulation is constant. The accumulation of storage reserves accounts for most of the increase in seed dry weight during this phase

Phase III (end of seed growth/ physiological maturity): begins when the accumulation of reserve materials slows down. The third phase is when the seed undergoes further desiccation after physiological maturity. Eventually, seed reach harvest maturity, which is the moisture content (usually 15-20%) at which mechanical harvesting of the seed is possible.

The dry weight of an individual seed increases slowly during an initial lag phase (phase I), followed by a phase when the growth rate is at its maximum and is constant (phase II), after which the growth rate decreases to zero at physiological maturity (maximum seed dry weight), phase III.

Physiological Maturity: is defined as the occurrence of max seed dry weight and represents the end of dry weight accumulation and the end of seed filling period. At physiological maturity assimilate no longer moves into the seed. Seed moisture content at physiological maturity is relatively high and well above harvestable in most crops.

Harvest Maturity: when the seed has dried to harvestable moisture level i.e. when 95% of the pods are dried.



Graphical representation of 'grand period of growth' (a sigmoid curve) in maize plant.

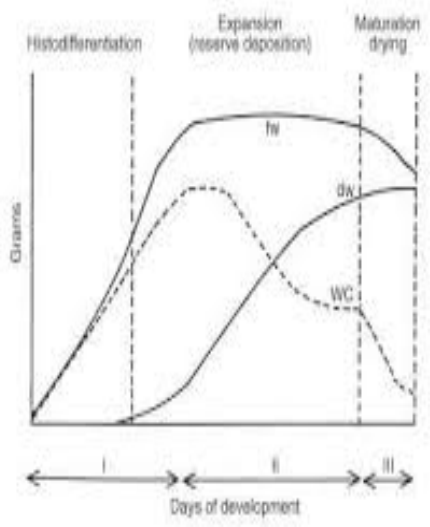


Figure 3: **Phases of seed development**

2.4. Environmental Effects on Seed Development

In addition to the genetic factors of the plant**,** the environment in which the seed forms affects its development. This is often illustrated by changes in seed size and weight. Components of the environment that influence seed size and weight include soil fertility, moisture, temperature, light and position in the plant.

a. Soil Fertility: generally, plants that have been fertilized with the three major elements (N P K) produce large seeds than those which have not been fertilized. The increase in seed size is due to a greater seed development rate during the seed filling period as a consequence of increased nutrient availability. When examining the influence of individual elements on seed development N clearly has the greatest effect.

✓ Production factors can also influence seed development. Increased competition for limited nutrients by weeds or from crops as a consequence of narrow raw spacing and increased number of seed per row result in decreased seed size.

b. **Moisture:** prolonged droughts and reduced soil moisture content decrease seed size, particularly when these effects occur during flowering and seed filling. If drought occurs only before flowering its primary effect is on reduction in seed number while seed size is unchanged. The lack of soil moisture may reduce photosynthesis, which shortens the seed filling period, thereby reducing seed size.

c. **Temperature**: high temperature during seed development produces smaller seeds while low temperatures favor large seeds

d. **Light**: in general, reduced light to the parent plant results in smaller seeds. Partial shading reduces seed weight. Short days also reduce seed size. These effects of light may be due to the lack of light which decreases photosynthesis and result in smaller seeds.

e. **Position on the plant**: the position of the seed in the inflorescence can affect seed development rate. E.g. Distal seeds in a wheat spike have slower growth rates and shorter grain filling periods than proximal seeds.

✓ Corn seeds at the tip of the ear are smaller than those at the base which has been attributed to inadequate photosynthate supply

CHAPTER 3: SEED DORMANCY

Seed dormancy is where the viable seed of a given species fail to germinate under conditions of moisture, temperature and oxygen supply which are normally favorable for the later stages of germination and growth of that species. A common misconception of seed dormancy is that it is merely a resting state in the absence of suitable germination conditions. This state is often called quiescence. ***Quiescence*** is a state of arrested development of the seed due to the absence of suitable germination conditions. However, true seed dormancy is a state in which seed is prevented from germination even under environmental condition normally favorable for germination.

Types of seed dormancy

Dormancy may be primary or secondary

A. Primary Dormancy: divided into two

- Exogenous dormancy
- Endogenous dormancy

I. Exogenous dormancy

- Dormancy caused by the property of embryo coverings pericarp, testa, endosperm
- Is a form of dormancy in which the essential germination requirements (water, light, and temperature) are not available to the embryo so that it is failed to germinate.

This form of dormancy is related to the physical properties of the seed coat including

1. Impermeability to water
2. Low permeability to gases
3. Mechanical restriction of embryo growth

1. Impermeability of seed coat to water

This appears to be one of the simplest but most effective means of delaying germination. The impermeability is caused by both genetic and environmental factors. Genetic control of seed impermeability has been reported for alfalfa and bean varieties. Several complex environmental interactions (weather and soil conditions) during seed development and ripening contribute to the seed coat's impermeability to water. Agriculturally, seeds that exhibit seed dormancy via impermeability of water due to seed coat are known as hard seeds. The impermeability to water may be due to the presence of cuticle and well-developed layers of palisade cells or both. Heavy deposits of cutin, suberin and lignin are common in the teguments of many legume seeds and other hard seed coated species.

2. Low permeability of seed coat to gases

The several layers of tissue surrounding the embryo might limit the capacity for gases exchange by the embryo either the entry of oxygen may be impeded or the escape of CO_2 may be hindered. In many species seed such as graminae and compositeae, the seed coat is selectively permeable, permitting water to enter but not for oxygen.

3. Mechanical restriction of the embryo growth

The coats of many seeds are made up of very hard, tough tissues, which clearly offer mechanical resistance to the growth of the embryo. This assumed due to the embryo cannot develop enough trust to rapture the seed coat during imbibitions and it is remaining ungerminated.

II. Endogenous dormancy

This type of dormancy is the most prevalent. Endogenous dormancy is caused mainly due to the inherent property of the seed. It is caused by:

1. Rudimentary embryo (morphological dormancy)

This type of dormancy is caused due to underdeveloped and under differentiated embryos. The seeds of some species are morphological immature when dispersal unit is shed from the mother plant. Immature embryos are relatively small and poorly differentiated and must grow and develop to ready for germination.

2. Physiological dormancy

This type of dormancy caused due to

a. Presence of inhibitor and absence of promoter

The dormancy may be caused a result of the absence of growth promoters and the presence of growth inhibitors. For example, gibberellins present for seed germination to occur and cytokines can prevent this expression.

b. Osmotic Inhibitors

Substances possessing high osmotic potential can inhibit the germination of seed, sugar and salt compounds in sufficient concentration may compete with seed for water and as a result, the seed never becomes fully imbibed and thus remain ungerminated. E.g. Fruit seeds of palm and peach trees.

c. Metabolic inhibitors

Certain compounds present in the seed may inhibit specific metabolic pathways. For example, Cyanide (CN_3) inhibits seed germination through their effect on respiration phenolic compounds (caumarin) can also inhibit seed germination and widely occurred in agricultural seed and regarded as natural germination inhibitors. Abscises acid (ABA) inhibit the enzyme syntheses that are important in the early stages of germination.

B. Secondary seed dormancy

Seeds, which ordinarily would germinate, immediately if planed under favorable conditions may be thrown into dormancy by an unfavorable environment so that they will not germinate even when conditions become favorable. The dormancy is due to by being that under unfavorable environmental conditions.

Method of overcoming seed dormancy

The most used methods are:

Scarification-mechanical or chemical treatments that weakens or rapture the hard seed coat is known as scarification. This method is used when dormancy is due to the physical characteristics of the seed coat (exogenous dormancy).

a. Mechanical scarification

- Seeds rubbed by sand paper or mechanically scarified. Care should be taken not to cause any damaged to the axis of the seed.
- Absorption of water by seed is accomplished by piercing the seed coat with needle
- Brief immersion of the seed in boiling water is an effective method of breaking the hardiness of the seed coat of legumes
- Vigorous shaking of the seed

b. Chemical scarification

Many chemical used to cause degradation of seed coat. These include:

- ❖ Soaking hard-coated seed in concentrated or diluted sulfuric acid removes seed impermeability
- ❖ Use of selective seed coat enzymes such as pectinase and cellulose to degrade the seed coat
- ❖ Many seed coats contain water-insoluble compounds that retard water entry into the seed, organic solvents such as acetone and alcohol have been used to dissolve and remove those compounds and permit water into the seed

2. Stratifications- When dormancy is due to endogenous factors (embryo development or presence of inhibitors), seed is subjected to stratification, i.e incubation of seed at low temperature (0-5^{0}C) over a moist substratum for 5-10 days (to break dormancy) before placing it at optimum temperature for germination. Some seed may require prolonged stratification (2-6 months at 5-10^{0}C). It well known that physiological changes occur in imbibed seed exposed to low temperature (stratified seed). For most cereals, storage of dormant seed for one or two months at 15-20^{0}C (after repining during storage) is sufficient to allow maximum germination.

3. Light treatment

Some seed does not germinate in the dark, therefore, continuous or periodic exposure to light can be essential to break endogenous dormancy.

4. Treatment with growth regulators and other chemicals

Since endogenous dormancy may be due to the presence of germination inhibitors, application of low levels of growth regulators may break dormancy. Different groups of chemical have been reported to break dormancy. GA3 is the widely used chemical and found to be most effective in breaking dormancy in many cased. Potassium nitrate (0.2%) has also been found to be effective in breaking dormancy.

CHAPTER 4. SEED GERMINATION PHYSIOLOGY

4.1. Definition

Various definitions have been given for seed germination.

- ✓ To the seed physiologist, germination is defined as the emergence of the radicle through the seed coat.
- ✓ To the seed analyst, germination is the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions.
- ✓ Others consider germination to be the resumption of active growth by the embryo resulting in the rupture of the seed coat and the emergence of a young plant.

Some seeds are capable of germination only a few days after fertilization and long before their normal harvesting time; others are dormant and require an extended rest period or additional development before germination can occur.

4.2. Conditions necessary for germination

1. Sufficient moisture-Water is a basic requirement for germination. The uptake of water by the seed is the first process occurs during seed germination. Water causes swellings of seed content and raptures the seed coat, which facilitate the entry of oxygen and escape of accumulated carbon dioxide. Water is also essential for enzymes activation, breakdown, translocation and the use of reserve storage materials.

2. Suitable temperature-Dry seed withstand large extreme temperature. Water socked seed, however, is very sensitive to temperature variation and therefore, seed germination with in a normal range of temperature (15-30^{0}C). However, the minimum, optimum and the maximum temperature for germination of seed vary from species to species.

3. Suitable composition of atmospheric gaseous

Aeration of the soil is essential for germination. The process of germination is related to living cells and requires an expenditure of energy. Oxygen is necessary for aerobic respiration by which the seed gets the requisite energy for the growth of the embryo.

4. Light for certain seed species

Light is not indispensable for the germination of seeds. Seeds can germinate well even in total darkness. However, most seeds germinate better when they exposed to light.

4.3. Physiological changes during germination

1. Imbibitions-Water is essential for germination as it enters in the seed by imbibitions. During imbibition, the dry seed coat become softened and more permeable to water and gaseous which result into swelling of the seed.

2. Digestion -The stored food materials in the seed need to break down through digestion before it can be used in the germination process. Starches are digested to sugar, fats to fatty acid and the proteins to amino acid used in respiration during seed germination

3. Respiration -Respiration takes place in all living cells. During germination, the respiration rate is high energy is mainly librated form carbohydrate. The proteins are used mainly in constructive metabolism.

4. Emergence of essential structures- The radicle emerges usually through the micropyle. Some seeds possess structures and secrete substances, which aid in removing the seed coat during germination. Germination falls into two categories based on the fate of the cotyledon or storage organs.

1. **Hypogeal germination**: In hypogeal germination, the cotyledon and other storage organs (endosperm mostly) remain beneath the soil, while the plumule pushes upwards and the coleoptiles is become a temporary sheath which endorse the plumule and provides protection and rigidity to the emerging plumule as it pushes through the soil.

2. **Epigeal germination**: In epigeal germination, the hypocotyls elongates and pushes the epicotyls and cotyledons above the ground and leaving the remainder of the seed below the surface.

Pattern of seed germination-Most seeds undergo a specific sequence of events during germination. The major events are *imbibition, enzyme activation, initiation of embryo growth, rupture of the seed coat, and emergence of the seedling*.

Imbibition

The early stages of imbibition or water uptake into a dry seed represent a crucial period for seed germination. Imbibition is an essential process initiating seed germination. It is the first key

event that moves the seed from a dry, quiescent, dormant organism to the resumption of embryo growth. Consequently, an orderly transition of increased hydration, enzyme activation, storage product breakdown, and resumption of embryo growth must occur. . Thus, any consideration of seed germination physiology and its resultant impact on stand establishment should initially focus on water uptake. The extent to which water imbibition occurs is dependent on three factors: (1) composition of the seed, (2) seed coat permeability, and (3) water availability.

Composition of the Seed: the principal component of seeds that is responsible for the imbibition of water is protein. Proteins are zwitterions that exhibit both negative and positive charges that attract the highly charged polar water molecules. The difference in imbibition of protein containing seeds compared with those containing starch is demonstrated by soybeans and corn. Soybean seeds typically imbibe 2-5 times their dry weight in water, while corn seeds imbibe 1.5-2 times their dry weight. Similarly, the embryo of cereal seeds can absorb about twice as much water as the endosperm can be explained by the greater proportion of protein present in the embryonic tissues. Legume species have shown that the embryonic axis characteristically had higher water binding properties than the cotyledons .E.g. Soybean embryonic axis hydrated more rapidly and completely than any other seed part due to its higher protein composition. Other chemical constituents of seeds also contribute to imbibition. The mucilages of various seeds increase imbibition as do the cellulose and pectins located in the cell walls. In contrast, starch molecules have little impact on imbibition even when large quantities of starch are present, as in seeds of many grasses. Starch, because of its uncharged structure, only attracts water at very acid pH or after high-temperature treatment--conditions that do not occur in nature.

Seed Coat Permeability: Entry of water into seeds is greatly influenced by the nature of the seed coat (or pericarp). Water permeability is usually greatest at the micropylar area where the seed coat is ordinarily quite thin. The hilum of many seeds also permits easy water entry. The same appears to be true in many grass seeds which possess a pericarp that completely surrounds the seed except at the pedicel end. This open, porous structure results in a more rapid hydration of the embryo that progressively moves from the radicle to the coleoptile end. A slower, more progressive wetting front simultaneously moves through the seed coat and into the endosperm. Seeds of certain species have special tissues around these natural openings that prevent water entry and contribute to hard seed coat (impermeable to water) dormancy. This hard-seediness has been attributed to small elongated pores and a high density of waxy material embedded in the testa epidermis. In other instances, hard seededness has been attributed to the presence of lipids, tannins, and pectic substances in the seed coat. The incidence of hard-seededness is both genetically and environmentally controlled and is greatest when seed maturation occurs under high temperature, high humidity conditions. The seed coat acts as a semi permeable membrane, permitting the entry of water and certain solutes while restricting others. For example, the leakage of the inositol pinitol from imbibing soybean seeds is substantially greater than for sugars such as sucrose/raffinose, stachyose, fructose, and glucose . The cuticle of wheat seeds has been observed to carry an electric charge that influences the permeability to various solutes.

Water Availability: The environmental forces that determine the rate of water imbibition by seeds are complex. The ability to imbibe water is dependent on cell water potential and is a result of three forces:

1. Cell wall matric forces. Cell walls and intracellular inclusions such as mitochondria, ribosomes, and spherosomes are characterized by the presence of membranes. These membranes possess charges that attract water molecules and contribute to the total cell water potential.
2. Cell osmotic concentration. The greater the concentration of soluble compounds, the greater the attraction for water.
3. Cell turgor pressure. As water enters a cell, it exerts a swelling force on the cell wall called *turgor pressure.* Unlike the cell wall matric forces and osmotic concentration that attract water molecules into a cell, turgor pressure, which is a result of the restraining force of the cell wall, tends to retard water absorption. However, most soils exhibit a high degree of hydraulic conductivity that replenishes the available water surrounding the seed as it continues the process of imbibition. Seeds possessing textured seed coats are more likely to have a greater seed-soil contact than smooth-coated seeds, and thus they will imbibe water more rapidly. A final factor is seed size. Small seeds possess a greater surface area to volume ratio than large seeds. This greater surface area permits them to have access to a greater amount of water than large seeds, which means that they will hydrate more rapidly.

Enzyme Activation

Dry seeds are characterized by a remarkably low rate of metabolism that is undoubtedly attributable to their low moisture content (which may be as low as 5 to 10% in unimbibed seeds), thus are said to be in a state of quiescence. As soon as the seed becomes imbibed, however, marked changes in its metabolism occur. A triphasic pattern of water uptake has been demonstrated during the germination of most seeds. Enzyme activation begins during Phases I and II of imbibition. During Phase II, the seed undergoes many processes essential for germination. Increased respiration and leakage of nutrients from the imbibed seed leads to loss of dry weight. Finally, in Phase III, root elongation is observed. The root becomes functional during this phase and is responsible for the increased water uptake noted in Phase III. The process of enzyme activation during Phase II of water imbibition serves to break down stored tissue, aid in the transfer of nutrients from storage areas in the cotyledons or endosperm to the growing points, and trigger chemical reactions that use breakdown products for the synthesis of new materials.

Initiation of Embryo Growth

Monocot seeds generally display a germination pattern similar to that exhibited by corn. During the first 120 hours of germination, there is a marked decrease in the dry weight of the endosperm with a concomitant increase in the dry weight of the embryonic axis. These changes are in part, a reflection of decreases in total nitrogen and insoluble protein that occur in the endosperm, and the subsequent translocation of these compounds to the emerging axis. Similar changes would be anticipated following endosperm starch hydrolyzation to maltose and then to glucose, which is then enzymatically altered to sucrose and translocated to the axis. In cowpea the major storage tissues, the cotyledons, undergo a decrease in dry weight as the hypocotyl and subsequently the epicotyl, show increases. Like corn, soluble carbohydrates, soluble nitrogen, and nucleic acid phosphorous levels decrease in the cotyledons and are found in the emerging embryonic organs of the hypocotyl, roots, epicotyl, and plumule. These events show that the storage tissues function primarily as reservoirs from which the emerging axis can draw nutrients for rapid germination and emergence.

CHAPTER 5: SEED QUALITY TESTING

5.1. Seed quality

Seed quality is one of the main factors affecting crop production potential. For seed to play a catalytic role in crop production, it should reach farmers in good quality.

High quality seed can be defined as seed of an adapted variety with high varietal, species, and physical purity; high germination and vigor; free from seed borne pests; and properly cleaned, treated, tested and labeled. Seed quality is a multiple concept made up of different attributes.

In technical terms, seed quality can be categorized into four major components:

1. Genetic seed quality: Genetic quality is the inherent genetic make-up of the variety contained in the seed, which provides the potential for higher yield, better grain quality, and greater tolerance to biotic or abiotic stresses. It is determined by those plant characteristics that result from the genetic potential of the embryo. Plant breeders through selection, introduction and hybridization using conventional or modern biotechnological tools develop new crop varieties for use. The gene and combinations of genes constituted in the variety define the genetic seed quality and therefore, its potential attributes such as grain yield and other agronomic characteristics. The physical, physiological and health seed quality contributes towards realizing these potential of the variety.

2. Physiological seed quality: Physiological quality is the viability, germination and vigor of seed, which determines the potential germination and subsequent seedling emergence and crop establishment in the field.

3. Physical seed quality: Physical quality includes freedom from contamination with other crops, common and particularly noxious and parasitic weed seeds, seed size, seed weight and seed lot uniformity.

4. Health quality (sanitary seed quality): Seed health quality includes the absence of infection/infestation with seed-borne pests (fungi, bacteria, viruses, nematodes, insects, etc.).

A complete formal seed quality control has comprises the following operations

1. Seed testing 2. Post control 3. Seed certification

5.2 Seed Testing

Seed testing is a science of evaluating the seed quality to determine its value for planting purpose. Knowledge of the various qualities of seed is greatly contributed to the agricultural development in the past and will continue in the future by enhancing crop production.

The objective of seed testing is

1. To determine their quality, i.e. their suitability for planting
2. To identify seed quality problem and their probable cause
3. To determine the need for drying and processing and specific procedure should be used
4. To determine if seed meets established quality standards or labeling specification
5. To establish quality and provide a basis for price and consumer discrimination among lots in the market.

- ✓ Seed sampling is important since it is physically and financially impossible to examine large number of seeds, a representative portion of the population is taken and examined; the portion is called sample. Collecting the sample is called sampling and conclusions about the population are based on the tests using the sample.

✓ The more the representative the sample, the more the accurate the conclusion. Therefore, sample seed for analysis should truly represent the bulk of the seed to be tested. The objective of seed sampling, therefore, is to obtain a sample of a size that is suitable for tests with the same constituents in the same proportion as entire seed lot.
✓ The basic technique is to sample randomly of seed using a method where every seed in the population has the same chance of being chosen.

The main tests are:
1. Physical purity analysis
2. Seed moisture analysis
3. Germination test
4. Viability test
5. Seed health test
6. Seed vigor test
7. Varietals (cultivar) purity test

Purity Analysis

Purity analysis determines the percentage of pure seed by weight and identifies the composition of any impurities, especially with regard to weed seed. The analysis separates the working sample into three components:

I. **Pure seed**: including any seed fragments that are larger than half the size of a whole seed. Immature, shriveled and diseased seeds are regarded as pure seed, if they can be identified as the species stated.

II. **Other crop seed**- they refer to any kind of seed or seed like structure of any plant species other than of the pure seed

III. **Weed seeds:** they refer to any kind of seed or seed like structure of unwanted or undesired plants

IV. **Inert matter**- including any other materials (soil, stones, chaffs, stems, leave etc.) and seed like structure from both crop and weed plants. Any seed fragments that are less than half-seed sized also considered as inert matter.

Seed Moisture Content Analysis

Seeds are usually stored for periods ranging from a few months to more than a year. The moisture content of the seed and temperature (relative humidity) in the storage has greatest effect on seed viability. Moisture testing is necessary at various stages in the seed chain:

- Before harvesting in order to assess whether the optimum harvesting (threshing) moisture content has been reached or not
- Before seed drying to assess the drying needs of the lot (for setting drier)
- Before and during storage
- At final packing

Seed moisture content (%)	Effect on seed
40-80	Moisture content of developed seed. Seed not mature enough for harvest
18-40	Seed physiologically mature, Seed susceptible to field deterioration, moths and insects are very active
13-18	Moths and insects can be damaging the seed
10-13	Seed store reasonable well for 6- 18 months in open storage Insects can still be a problem in susceptible seed
8-10	Very little insect activity. s e e d very susceptible to mechanical damage
4-8	Safe moisture content for sealed seed storage
0-4	Extreme desiccation can be damaging the seed

The moisture content is the difference in weight before and after drying. It is expressed as a percentage

Moisture content (%) = Initial weight of seed/loss of seed

Germination Test

The main objective of seed germination test to obtain information about the field planting value of the seed lot.

Procedures for germination test

Germination tests are carried out on pure seed fraction derived from purity analysis.

1. Randomly select seeds from the pure seed component of the purity test
2. Place replicate (usually containing 100, 50 or 25 seeds) on or roll them in moistened paper or sand or Petri dish
3. Germinate the seeds in incubators and count germination at regular intervals during the test period. The number of each replicate is interpreted as falling into one of the following categories.

1. Normal seedling: those which show a capacity for, continued development into a normal plant when grown in good quality soil under favorable conditions of moisture temperature and light. The assessment of normal seedling made on:

- Well-developed root system (the primary root should be intact with root hairs)
- Well- developed shoot system (the hypocotyls, coleoptiles, terminal buds and cotyledons should be intact with only slight defects)

2. Abnormal seedling: is unable to develop into a normal plant when it is grown under favorable conditions in good quality soil. Abnormal seedling assessed.

- Damaged seedling in which any essential structure is missing or badly damaged
- Deformed or unbalanced seedling caused by internal disturbances of physiological or biochemical e.g. Chlorophyll deficiency.
- Decayed seedlings in which the essential structure is diseased or decayed due to fungal or bacterial infection.

3. Ungerminated seed: Seeds which are not germinated by the end of the test period. These include

- **Hard seed**: seeds that has not absorbed water
- **Fresh ungerminated seed**: dormant seed that absorbed water and maintained its fresh condition i.e. is not discolored or moldy and has a firm turgid texture.
- **Dead seed**: that has absorbed water and a soft, non-turgid texture discolored and is often moldy.

Moistened paper and the rolled towel method usually used because they are relatively cheap and easy to prepare. Covered trays and Petri dishes used for small seeds. Evaluation of seedlings is done when all essential seedling structures are visible and have grown or develop to such an extent that their characteristics can be clearly seen.

Seed Viability Test

Seed viability (germination potential) means that the seed is capable to germination and producing a normal seedling. In other words, viability of a seed denotes the state of being aliveness, metabolically active and possesses enzymes capable of catalyzing metabolic reactions needed for germination and seedling growth. A germination test is usually the best method for estimation seed viability. However, all viable seeds may or may not germinate because of the seed may dormant, hard seed or slow germinating seed. In such cases, it is necessary to carry out a viability test on the seeds, which remain un germinated at the end of the test.

The most commonly used for viability test is Tetrazolium test, utilizing 2,3,5 – triphenyl tetrazolium chloride (TTC). The principle of TTC test is based on the response of all living cells of the seed which can reduces a colorless solution of 2,3,5 – triphenyl tetrazolium chloride (TTC) in to red colored compound. The reduction of the chemical takes places in the seed by the action of a group of enzymes known as dehydrogenase. The enzymes are involved in H-transfer during respiratory activity of the biological system.

Procedures of the test

1. Seeds are soaked into water for a few hours and cut into two longitudinally to expose the embryo
2. The seeds are then soaked in 1% solution of TTC in the dark for one or two hours
3. At the end of this period, the embryo of living seeds will stain reddish while dead embryo and dead part of the embryo will remained unstained

Advantages of TTC test

- Quick estimate of seed viability
- When the seed is dormant, or very slow in germination, a viability test is extremely useful.

Disadvantages of TTC test

- It is difficult to distinguish between normal and abnormal seedlings
- It doesn't differentiate between dormant and non-dormant seeds
- Since the TTC test does not involves in germination, thus the micro-organisms harmful to germination seedlings are not detected
- The knowledge of the seed and the seedling structure is essential for conduction of the test.

Seed health test

Seeds can be carries of seed-borne pathogens such as viruses, bacterial, fungi and nematodes. Some of these are transmitted; i.e. the seed-borne disease can indeed affect the germination seedling or the resultant plant. Cultural methods aimed at minimizing the risk of infection and seed treatments may apply to cure an infection.

Seed health testing can check on the effect of these measures and can be especially useful in preventing the introduction of new pathogen into an area. The health testing method should be

simple, cheap, and quick and should facilitate identification of the pathogens. Seed health testing may be done by visual assessment or followed more advanced seed health testing.

Visual assessment is by observing the presence of sclerotic, spots on seeds. The more advanced seed health testing includes:

1. **Blotter method**: involve the incubation of the seed on blotting paper. Seed-borne pathogen can be identified and the severity of the infection assessed based on vegetative growth rate, emergence of the fruiting bodies and symptoms on the seedlings.
2. **Agar test: -** involves the incubation of the seed on a sterile media or either a general agar or media that specifically promote the growth of certain pathogens
3. **Serological technique**: based on the interaction of antigens and antibodies are specific test for a particular viral diseases.
4. **Grow-out tests**- observe symptoms on the seedlings.

Seed Vigor test

The shortcoming of the standard germination test is that it gives little information about the seedling vigor and germination potential (seed viability) of the seed lot. Seed vigor or germination energy is comprises those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. It indicates the capacity of the seed lots to produce a good crop stand under sub-optimal field conditions.

Seed vigor is affected by genetic constitution, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, weight, pathogen attack, mechanical damaged to the embryo or seed coat, drying temperature etc.

For example, higher temperature speed up drying, but drying injuries may occur. This is not immediately detected by normal germination test. However, vigor tests may show that the slowly dried seed is more vigorous than seed that is dried fast at a higher temperature. When such seed is stored under less ideal storage conditions, the fast dried seed deteriorates much more rapidly than the slowly dried seed lot.

Varietals Purity Test

Varietals purity refers to whether a variety is true-to-type and if it is still has the original genetic make-up. For pure line varieties, all plants are similar in morphological, physiological, cytological and chemical characters. Varietals (cultivar) purity is an important attribute of the seed quality, because it guarantees that the genetic make-up as defined by the breeding methodology is still present when the seed of improved varieties reaches the farming community.

Farmers can exploit the genetic potential of an improved variety if the genetic makeup is not diluted during multiplication. Varietals purity tests establish whether a field or a seed lot of a variety is sufficiently pure, i.e. whether a sufficiently large percentage of seed, seedlings or

mature plants conform to the original description of the variety. It can be controlled by inspection of plants in seed multiplication fields or examining seeds or seedling in the laboratory or growing plants in field plots.

NB. Although each component of seed quality has significance under specific condition, however, it is possible to rank them in terms of relative importance. Germination seems the most critical, followed by vigor and sanitary (health test). Failure in germination may lead to a total crop failure and similarly, less vigorous seed may fail to emergence and drastically affect plant population in harsh environment, which reduce the overall production potential of the crop. The same is true for seed health. If the pathogen is exclusively seed-transmitted, has a rapid transmission rate and is influenced by weather.