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**College of Agriculture and Natural resources**

**Department of Plant Science**

**Seed Science and Technology (For 2nd year Plant science students)**

**Course Code: plsc 2034**

**By:**

**Mekonnen Gebeyaw (MSc.)**

**Mekdela Amba University, Ethiopia**

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**CHAPTER ONE:**

**1. INTRODUCTION**

**Why people are interested in science?**

Because of our highly developed mental skills to investigate the how, the why, and the when of natural events and to satisfy human curiosity. Science is an effort to make the chaotic diversity of our sense experience corresponds to a logically uniform system of thought (A. Einstein 1940).

* 1. **Definition of science and technology**

**1. Science is a process**

* It is determined by observation, hypothesis, experimentation, measurement and analysis.
* Conceptualization of new ideas from the abstract (theoretical rather than physical or concrete) to the particular.

**2. Science is a product**

* Systematized, organized body of knowledge based on facts.
* Concerned with verifiable concepts.
* It is the variety of knowledge, skills, physical resources and technologies that taken together in relation with one another.

Technology on the same view is defined as both a **PROCESS** and a **PRODUCT.**

1. Technology as a process: It is the application of science.
2. Technology as a product: A system of know- how, skills, techniques and process.

**Science and technology:** defined as a system of know- how, skills, technique’s and process which enable society to produce, distribute, put in, maintain or improve goods and services needed to satisfy human needs.

**1.2. Definition of Seed Science and Technology**

**Cowan, 1973:** Defined Seed Technology as that “discipline of studies having to do with seed production, maintenance, quality and preservation”.

**Feistritzer, 1975:** Defined Seed technology as “the methods through which the genetic and physical characteristics of seeds could be improved. It involves such activities as variety development, evaluation and release, seed production, processing, storage and certification”.

* Seed technology includes the development of superior crop plant varieties, their evaluation and release, seed production, processing, seed storage, seed testing, seed quality control, seed certification, seed marketing, distribution and research on seed aspects.
* It is a multidisciplinary science encompassing a range of specific disciplines such as: **1**. Development of superior varieties, **2.** Evaluation, **3.** Release, **4.** Production, **5.** Processing, **6.** Storage**, 7.** Testing **8.** Certification/quality control, **9**. Marketing and distribution, **10.** Seed pathology, **11**. Seed entomology, **12**. Seed physiology and **13.** Seed ecology.

**1.3. Major Disciplines in Seed Science and Technology**

**Plant Breeding and genetics:** in addition to development of new varieties, it also associated with maintenance of nucleus and breeders seed.

**Agronomy:** offer suitable package of practices of growing, harvesting and handling of seed crops.

**Plant pathology:** increased interest in relation to distribution of disease free seed. They give package in regard to appropriate seed treatment, plant protection etc. they also be involved in seed health testing techniques, plant quarantine etc.

**Entomology:** package in regard to pest (insect) control during production and storage of the seed.

**Plant Taxonomy:** important in identification of various crop and weed seeds.

**Plant/Seed physiology:** important in understanding planting seed quality problems and provide solutions to this problems. They also associated with seed germination. Seed vigor and viability testing techniques.

**Agro-economics:** gives guarantee in relation to seed marketing problems and decisive suitable marketing and distribution system associated with seed price fixation etc.

**Agricultural engineering:** associated with development of technology to manufacture in suitable seed planting, harvesting machinery for seed crops and also seed drying, seed processing machinery, seed testing equipment etc.

**Agricultural extension:** involved in popularizing (awareness creation) on the use of high quality seeds of high yielding varieties among the farming community.

**1.4. Definition of Seed**

Seed: - It is a complex biological structure consisting of a plant in miniature and food reserves protected by covering coats. A miniature plant possessing a remarkable capacity to ensure that the new individual starts life in the right place at the right time. Furthermore;

* Seed is a material which is used for planting or regeneration purpose.
* Seed is a fertilized matured ovule covered with seed coat.
* Structurally a true seed is a fertilized matured ovule, consisting of an embryonic plant, a store of food and a protective seed coat, a store of food consists of cotyledons and endosperm.
* Seed may be sexually produced matured ovule consisting of an embryo, endosperm or cotyledon with protective covering (seed coat).
* It also refers to propagating materials of healthy seedlings, tuber, bulbs, rhizome, roots, cuttings, all types of grafts and vegetatively propagating materials used for production purpose.
* The embryo is an immature plant from which a new plant will grow under proper conditions.
* The embryo has one cotyledon or seed leaf in monocotyledons, two cotyledons in dicotyledonous plants.

**1.5. Difference between Seed and Grain**

|  |  |
| --- | --- |
|  **Seed** |  **Grain** |
| * It should be viable.
 | * Not need to be viable.
 |
| * It should have maximum genetic & physical purity.
 | * It should not have a must maximum genetic & physical purity.
 |
| * Treated with pesticide /fungicide to protect seed against storage pests and fungi.
 | * It should not have a must maximum genetic & physical purity.
 |
| * Respiration rate and other physiological and biological processes should be kept at low level during storage.
 | * Not treated with any chemicals, since it used for consumption purpose.
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| * Production is technically organized (Scientific).
 | * No such specifications especially on respiration rate and other physiological and biological processes should be kept at low level during storage.
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| * It should satisfy all the seed quality attributes.
 | * It is not a must that production is technically organized (scientific).
 |
| * It should fulfill minimum seed certification standards. Ex: Germination
 | * It should not a must to satisfy all the seed quality attributes.
* It should not require for satisfying minimum seed certification standards.
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**1.6. Role of Seed in Agriculture**

**1. A carrier of new technologies:**The introduction of quality seeds of new varieties wisely combined with other inputs significantly increase in yield levels.

**2. A basic tool for secured food supply:** The successful implementation of the high yielding varieties program in India has lead remarkable (outstanding) increase in production and to a new assessment of future development potential. As a result, food imports from other countries have been substantially brought down in spite of the rapid population increase.

**3. The principal means to secure crop yields in less favorable areas of production:** The supply of good quality seeds of improved varieties suitable to these areas is one of the few important immediate contributions that seed technology can make to secure higher crop yields.

**4. A medium for rapid rehabilitation of agriculture in cases of natural disaster:** Widespread floods and droughts in various parts of the world have focused attention on this recurrent crisis and the accompanying threats of famine and starvation. The assistance operations by FAO (Food and agriculture organization) show that it would be much more economical if the governments had National Seed Reserve Stocks at their disposal. In brief the role of seed technology in Agriculture sector is timely supply of quality seeds for reasonable price.

**5. Raw materials or multiplication of plants that produce useful materials for manufacture:** fibers, wood .oils, beverages, spices, medicines, detergents and a wide range of industrial products.

**CHAPTER TWO:**

**SEED FORMATION AND SEED DEVELOPMENT**

**2.1. Reproduction Process in Plants**

Plant reproduction- is a central to survival of the species and it’s accomplished either sexually or asexually.

**Sexual reproduction -** involves the development of a new individual from a mature individual and an active participation of sexual cells or nuclei. This process promotes the renewal of individual from the fusion of male and female gametes.

**Vegetative propagation or asexual reproduction**

* Often the result of modification plant vegetative structures such as stolen, rhizomes, bulblis, tubers, tillers and others that process the ability to regenerate the mother plant.
* This also accomplished by plant cells or tissues (micro propagation) and apomixis (production of seeds and vegetative propagules by asexual methods).

**2.2. Floral Induction**

Sexual reproduction is first marked by the formation of a flower. Because of the production of flowers and seeds is energy intensive, most plants must first develop an adequate vegetative structure before flowering can occur. Once the plant has developed sufficient vegetative structure, exposure to appropriate flowering stimuli such as light or temperature creates a change from a vegetative to a reproductive meristem. Fortunately, this event is regulated and synchronous. Without flowers appearing simultaneously, the act of sexual reproduction would be difficult. For example, in corn if the male tassel flower and female silk flower did not appear together, the process known as nicking, fertilization would not be possible.

A typical flower consists of four main parts: sepals, petals, stamens (the male reproductive structures) and pistil (s) (the female reproductive structure (s)). When all four of these parts are present on one flower, the flower is complete. If any of these four parts are missing, the flower is incomplete. A perfect flower has both stamens and pistil (s) but may lack sepals, petals or both. An imperfect flower lacks either stamens or pistil (s). In addition, some plants produce staminate and pistillate flowers on the same plant and are might said to be monoecious (e.g., corn). The reproductive structures of a flower are the stamens and pistil (s).



**Development of pollen or male gametophyte**

**Structure of anther**

Each anther is a bilobed structure with each lobe containing two pollen sacs. In total, there are four pollen sacs in which pollen grains are produced. The two lobes of anther are joined by a connective that contains the vascular bundle from filament which carries the nourishment.

**Structure of pollen sac**

Each pollen sac is termed as a microsporangium and is filled with number of large sized cells called sporogenous cells or microsporocytes. A microsporocyte has abundant cytoplasm and a prominent nucleus. Each microsporocyte undergoes mitotic divisions and produces a number of microspore mother cells, also called as spore mother cells.

**Development of spore mother cell**

Each spore or pollen mother cell is diploid in nature. It undergoes meiotic (meiosis) divisions and produces four haploid microspores. Each microspore develops into a pollen grain. The process of formation of haploid microspore from diploid pollen or spore mother cell through meiotic division is known as micrsporogenesis. On further development, each microspore gets separated and forms a thick outer wall or exine which is specific to a species. As the pollen grains are formed, at about the same time, the anther ripens and the wall between the paired pollen sac disintegrates. The anther splits open along the two lines of weakness and the pollen grains are released.

**Structure of a pollen grain**

Each grain is covered by a thick wall having two layers.

**Exine:** It is outer, thick and sculptured structure. It is made up of a complex substance sporopollenin which is supposed to be one of the most resistant biological materials, which enables the pollen grains to survive in unfavorable conditions for a long time, may be millions of years. The regions where exine is thin or absent are known as germ pores. A pollen tube emerges from these germ pores at the time of pollen germination.

**Intine:** It is the structure inner to exine, thin and smooth. It being thin and equivalent to cellulose wall, gives rise to pollen tube at the time of pollen germination.

**Development of ovule and embryosac or female gametophyte**

**Formation of ovule**

Ovule development occurs within the ovary, which provides a location for nurture and development of the female gametophyte, a site for its sexual fusion with the male gametophyte and ultimately a package for embryo development, survival and eventual re-growth. Ovule growth begins as a small outgrowth (tiny knob) within the nucellus. Nucellus is the multilayered main body of ovule which is enclosed in one or two protective layers called integuments except for a small pore at one end. As megasporogenesis and megagametogenesis continue, the region of the nucellus which is to become the ovule enlarges and differentiates into definite morphological characteristics.

Secondary outgrowths or collars (integuments) soon appear around the outside edge of the nucellar outgrowths and envelop it. These usually consist of the inner and outer integuments and ultimately become the testa (seed coat) of the mature ovule. The developing ovule is commonly attached to the placenta by the funiculus. The scar on the ovule made where the funiculus detaches at maturity is known as the hilum. The point where the integuments meet at the nucellar apex is the micropyle and the region of integumentary origin and attachment, usually opposite the micropyle, is the chalaza. The micropyle is generally at the lower end of the ovule and serves as a passage for the entry of the pollen tube. Between the chalaza and the hilum of many species is an area known as the raphe.

**Development of megaspore mother cell**

The seeds of angiosperm originate from meristematic tissue of the ovary wall called ovule primordia. In species with simple ovaries, these primordia are usually located near the structure of the ovary wall where the carpel is fused. In species with more than one carpel, or with polycarpellate ovaries, the seeds form at the fusion of the carpels or along the septa, or central carpel axes, depending on the type of placentation.Within the nucellus or specialized tissue of the carpel, one cell, known as the archesporial cell, develops special characteristics that distinguish it from adjacent cells. As this cell increases in size, its nucleus becomes larger and the cytoplasms grow denser in preparation for cell division. The first division results in a megaspore mother cell and a parietal cell. Usually the parietal cell remains undivided and soon deteriorates, however, in some species; it undergoes further division and contributes to seed formation. The diploid megaspore mother cell undergo a two step cell division known as meiosis and give rise to four haploid cells or megaspores. One cell develops into haploid megaspore and remaining three degenerates. This process of formation of megaspore is known as megasporogenesis.

**Pollination**

It is the transfer of pollen grains from an anther to the stigma. After the pollen grains are shed from the anthers, they can reach stigma by number of means. The flower could be self pollinated or cross pollinated e.g. wind, insect, human and water etc...

**1. Self pollination:** It is when the pollen is transferred from an anther to a stigma in the same flower or to a stigma of another flower on the same plant. It is generally May not dependent on any external agency for pollination. The self pollination could be of two types:

**i. Autogamy:** Self pollination in the same flower within the plants having bisexual flower. Example: rice, wheat, pea, etc.

**ii. Geitonogamy:** It is a kind of self pollination where flowers could be bisexual or unisexual but

are borne by the same parent plant. The pollens from one flower are deposited on the stigma of

Another flower borne on the same plant. It may need an external agency like wind or insects.

**2. Cross pollination:** It is the transfer of pollen from the anther of one plant to the stigma of another plant. It involves two separate plants and outside agents like wind, water, bird, insects, etc. The agents could be biotic or abiotic.

**Agencies for cross pollination**

**i.** Wind pollination or anemophily: Maize, Oats, Coconut palm, *Cannabis* etc

**ii.** Water pollination or hydrophily: *Hydrilla*, *Zostera marina*, etc

**iii.** Insect pollination or entomophily: Mustard

**iv.** Bird pollination or ornithophily: Red silk cotton etc.

**Growth of pollen tube and fertilization**

**Growth of pollen tube**

After pollination, the main events that lead to fertilization are as follows.

* As the pollen grain lands on the stigma, if the stigma is unripe or pollen is of different species, no further development takes place.
* If stigma is ripe and of same species, the pollen begins to germinate on the stimulus of a sucrose solution secreted by epidermal cells of stigma.
* The intine along with its content emerges out in the form of pollen tube.
* Each pollen tube grows through the stigma and style to the ovary.
* Each pollen tube has two nuclei- the vegetative or tube nucleus or a generative nucleus.
* The tube nucleus is at the growing tip of the pollen tube.
* As the tube grows, the generative nucleus divides mitotically to produce two male nuclei also known as male gametes.
* The tube grows and passes through the micropyle into the ovule.
* The tube nucleus degenerates and the tube bursts releasing two male gametes into the embryo sac of the ovule.

**Fertilization**

One of the two male nuclei unites with the egg cell. This is known as fertilization and produces

fertilized egg or a diploid zygote. The other male nucleus fuses with the secondary diploid nucleus (made up of two polar nuclei) and forms a tiploid nuleus or primary endosperm nucleus. This is known as triple fusion. Since the process of fertilization occurs twice in the embryo sac, it is called as double fertilization. It is unique to flowering plants. Results of double fertilization are:

**i.** A diploid zygote (2N) that divides mitotically to form the embryo plant.

**ii.** A triploid nucleus (3N) or primary endosperm nucleus that gives rise to a mass of tissues that

Develops into the endosperm of the seed. It provides nourishment to the growing embryo plant.

**2.3. Seed Development (Maturation)**

* After Induction of flower and differentiation, flower parts are considered as the starting points of seed development.
* The process of seed development is controlled genetically and involves an organized sequence of changes from ovule fertilization to the point in which the seed becomes independent from the parent plant.
* Seed maturation is a process comprising a series of morphological, physical, physiological and biochemical changes that occur from ovule fertilization to the time when seeds become physiologically independent of the parent plant i.e., they reach physiological maturity (Delouche, 1971).

The seed development process from ovule fertilization to physiological maturity can be divided into four phases according to Dure (1975) and Adams and Rinne (1980).

* Phases I and II: comprises cell division and expanation.
* Phase III: Reserve accumulation occurs as seed dry mass increases.
* Phase IV: At the end of phase III, Seed moisture loss is intensified (buildup).

**2.3.1. Components of Seed**

**Seed coat**

It is the outer covering of seed and gives protection. It develops from the two integuments (the outer layer) of ovule. Outer layer of the seed coat which is smooth and rough is known as the testa and is formed from the outer integument. The inner layer of the seed coat is called the tegmen and is formed from inner integument.

**Embryo**

It is the mature ovule consisting of an embryonic plant together with a store of food, all surrounded by a protective coat, which gives rise to a plant similar to that of its mother.

**Radicle**

Primary root of a plant packed down in the embryo is the radicle, which forms the primary root of the young seedling. It is enclosed in a protective cover known as **coleorhiza.**

**Plumule**

It is the first terminal bud of the plant packed down in the embryo and it gives rise to the first vegetative shoot of the plant. It is enclosed in a protective cover known as **coleoptile**.

**Cotyledon**

Cotyledons are the compressed seed leaves. A single cotyledon (Scutellum) is present in monocots while two cotyledons are present in dicots; hence they are named as **monocots** and **dicots,** respectively. In dicots they serve as storage tissue and are well developed, while scutellum is a very tiny structure in monocots.

**Endosperm**

Endosperm is formed through double fertilization. It stores food for the developing embryo.

**Hilum:** It is the scar (mark) mostly white or black in color present on the lateral side of the seed. It represents attachment of the seed stalk to placenta (umbilical) of the fruit to mother plant (e.g.) Pulses.

**Micropyle:** The point where the integuments meet at the nucellar apex has been referred as micropyle. Water and gases.

**CHAPTER THREE:**

**SEED DORMANCY**

**3.1. Definition:**

It is common observations that seeds of many plant species do not germinate when freshly harvested even under favorable conditions. They need a period of rest/ storage before they become capable of germination. Inability of viable and mature seeds to restart growth immediately after harvest in an environment normally favorable for the germination of the concerned plant species is known as seed dormancy. The period of dormancy varies from a few days to several years depending on the plant species.

**1. True dormancy/primary dormancy/innate dormancy:** due to chemicals/physiological features of a seed.

**2. Enforced dormancy/imposed dormancy/quiescence/ secondary dormancy:** due to unfavorable environmental conditions, Example:

* Exposure of dry barley seed to temperature of 50-90 0C.
* Seven and near to seven days storage of winter barley at high moisture content at 20 0C.
* Placement of seed under water in dark condition for 3 days 2 0C.

**3.2. Significance of seed dormancy**

**Advantages:**

1. Storage of seeds is prolonged, it is a survival mechanism.

2. Seed can pass through adverse situation /conditions.

3. Prevents the insitu (in its natural place) germination.

**Disadvantages:**

1. No uniform germination.

2. Difficult to maintain plant population.

3. Interferes in seed testing procedure.

**3.3. Dormancy Classification**

Nikolaeva (1969 and 1977) classified dormancy into three broad classes below;

**I. Exogenous Dormancy:** Dormancy is due to some features of the seed located outside the embryo.

**A. Impermeability of seed coat to water**: due to seed coat structure, which is hard enough to restrict the entry of moisture into the seeds, thereby preventing seed germination.

**B. Impermeability of seed coat to gases;** is related to the insufficient intake of oxygen by seeds due to impermeability of seed structure enclosing embryo.

**C. Mechanical resistances of seed coat:** growth of embryo is checked due to extremely hard seed/fruit structure such as seed coat, endosperm per carp etc., Ex: Acacia species.

**D. Inhibitors present in seed coat/endosperm:** biochemical substances present in seed coat or endosperm block the germination of embryo.

**II. Endogenous dormancy:** the reason for dormancy is present within the embryo

**A. Incomplete embryo development:** due to an incomplete development of the embryo. In such cases, germination does not occur until the embryos develop to their normal size.

**B. Inhibitors present within the embryo:** Dormancy arises from metabolic blocks produced by biochemical substances called inhibitors present within the embryo. In such cases germination can commence only when these inhibitors are leached out of the embryo Ex: Xanthium, Fraximus.

**III. Combined Dormancy:** dormancy is produced by a combination of two or more factors which act in complementary (Harmonizing) fashion.

**3.4. Factors that control Dormancy induction**

* Seed dormancy is a typical quantitative genetic trait, which means involving many gens and influenced substantially by the environment during seed development, and then leads to continuous (non-discrete) phenotype variation.
* Some environmental factors affecting seed dormancy include: temperature, water availability and mineral nutrition.

**3.5. Methods to overcome dormancy**

**I. Natural breaking of dormancy:** in nature dormancy terminates when embryo gets suitable environment such as adequate moisture, aeration and temperature. The impermeable seed coat present in many species became permeable due to the rupturing of softening action of natural agents like microorganism, high or low temperature, humidity, fiber and abrasion due to wind or digestive tracts of birds and animals which feed on these seeds.

**II. Treatments to break Dormancy:** the various treatments for overcoming dormancy may be divided into the following three groups.

**1. Seed coat treatments:**

This treatment aim at making hard seed coat permeable to water or gases either cracking or softening them. The process is usually referred as **scarification.** These treatments are either physical or chemical in nature.

**A. Scarification:**

**i. Acid scarification:** treating seeds with concentrated acids like sulphuric acid, Hydrochloric acid etc…

**ii. Thermal scarification:** the seeds are treated with different temperatures and gases.

**iii. Mechanical scarification:** The seed coat is damaged using mechanical means. Rubbing seeds on Sand paper or by using mechanical scarifies. Making small incision by piercing a needle as in bittergourd. Removing of entire seed coat by rubber.

**2. Embryo treatments:**

**1. Stratification:** the incubation of seeds at a suitable low temperature (Usually 0-5 0C) over a moist substratum before transferring them to a temperature optimum for germination. Examples; Mustard and rape seeds.

**2. High temperature treatment:** in some species, incubation at 40-50 0C for few hours to 1-5 days may be effective in overcoming dormancy. Example; Rice seeds more than 15% seed moisture treated in hot water of 40 0C for 4-5 hours.

**3. Chemical treatments:** alternatively growth regulators or other chemicals may be applied to

Induced germination growth regulators commonly used GA, kinetin and thio-urea.

**CHAPTER FOUR:**

**PHYSIOLOGY OF SEED GERMINATION**

**Seed germination**

* Fundamental for crop/food production
* Full fills role of seed as a plant multiplication unit.

**4.1. Definition:**

* Seed physiologist: protrusion of the primary root. It says nothing about other essential characteristics: the epicotyls and hypocotyls.
* Seed technologist: emergence and development from the seed embryo of those essential structures which are inductive of the ability to produce a normal plant under favorable conditions. It focuses on the reproductive ability of the seeds, am essential objective in agriculture.
* Others: Resumption of active growth of the embryo.

Seed germination types; based on location of storage reserves;

* Epigeal germination (epi- upon, ge-earth): the cotyledons are raised above the ground where they continue to provide nutrient support to the growing points. During root establishment, the hypocotyls’ begin to elongate in an arch that breaks through the soil, pulling the cotyledon and the enclosed plumule though the ground and projecting them into the air. Cotyledon turn green and leaf like when the stored food is finished but ultimately they shrivel up and fall off.
* Hypogeal germination(hypo-below, ge-earth): the cotyledons or comparable storage organs remains beneath the soil while the plumule pushes upward and emerges above the ground. The epicotyle is the rapidly elongate structure. Cotyledon do not turn green, they dry up and fall off ultimately.



**4.2. Requirements for germination**

**Water:**

* It is essential for enzyme activation, breakdown, translocation and use of reserve storage material.
* Most seeds have critical moisture content for germination to occur.
* Once that critical seed moisture content is attained in the seed sufficient water is present to initiate germination and the seed is committed to that event and cannot turn back.
* If the internal moisture content decreases below the critical moisture content, seeds will essentially decay in the soil.

**Gases:**

* Air (20% O2,0.03% CO2, 79.97%N2)
* Oxygen is the most critical requirement for respiration
* High levels of carbon dioxide inhibitory
* Nitrogen no effect

**Temperature:**

* Different seeds have different temperature optima.
* Temperate seeds require lower temperature than tropical seeds.
* Wild species require lower temperature than domesticated species.

**4.3. Pattern of Seed Germination**

Although the exact sequence of events in seed germination varies among different plant species, the basic processes are similar:

* Water imbibitions
* Cell expansion and respiration
* Hydrolysis of food reserves in endosperm or cotyledons
* Transport of soluble metabolites to the embryo
* Synthesis of cellular constituents in embryo accompanied by cell division
* Rupturing of seed coat and emergence
* Seedling establishment

Seed coat takes up water by imbibitions which are purely a physical process and enclosed embryonic axis is gradually hydrated. Various hydrophilic groups such as –NH 2–OH,–COOH, etc. of proteins, polymeric carbohydrates, etc. found in seed coat attract dipolar water molecules and form hydrated cells around them resulting in the swelling of these substances. This water uptake by swelling is followed by intensive water uptake associated with germination. In many seeds, the embryonic root region (radicle) of the axis takes up water more quickly than the rest of axis and emerges first through the seed coat. In seed of most crops, radicle emergence (phase I) occurs within 24-36 hours after onset of water imbibitions. Imbibition of water causes more permeable seed coat to O2 & water and less resistant to outward growth of embryo.

As seed imbibes water, all the cells in embryo, cotyledons and endosperm become hydrated resulting in cell expansion and size increase. The hydration process may take 40-60 hours depending on the temperature and availability of water. Hydration, however, enables the cells in the embryonic axis and cotyledons to attain full turgor, accompanied by reorganization of the sub-cellular organelles and cellular membranes. Respiratory activities are initiated and some dry weight loss occurs. Initially there may be anaerobic respiration in embryo but it is soon replaced by aerobic one due to availability of O2. Food reserves in the endosperm or cotyledons are mobilized to provide substances for continued growth of the embryonic axis. The major food reserves in seeds are starch, nucleic acid, fat, protein and phytin. These reserves when mobilized and metabolized provide the embryonic axis with amino acids, nucleotides, nucleosides, sucrose and fatty acids. Several metabolic pathways involved in the conversion of storage fat to sucrose, an important pathway in fat rich seeds.

**Factors affecting Seed germination**

**1. Temperature**

There has been set the concept of minimal, maximum and optimum temperature for seed germination. The minimal and maximum temperatures are those temperatures that just permit germination whereas the optimal temperature is considered the one that permit the highest percentage of germination is the shortest period of time. Among cereals, wheat, barley and rye can tolerate temperature of 3-5C0 whereas maize and rice requires temperature above 8-12 C0 for germination. The temperature requirement of certain seeds depends on their age or physical condition. Freshly harvested seeds frequently require a very narrow range of temperature for germination, but as the seeds age, the temperature requirements become less exacting and eventually germination proceeds over a broad range of temperature. Seeds of some plants are able to germinate at low temperature whereas others require high ones.

**2. Gaseous environment**

The respiratory processes in seeds are stimulated soon after they imbibe water. After water addition the cells absorb water by imbibitions and increase in volume. This increase in embryonic volume is sufficient to break the seed coat and facilitate organ (radicle and plumule) emergence. With breaking of the seed coat, gas exchange can occur, thus providing an aerobic environment for further metabolism.Since respiration is essentially an oxidative process, an adequate supply of O2 must be available. If the O2 concentration is reduced substantially below that of air, germination of most seed is retarded. However, there are some notable exceptions; rice and other aquatic plants can germinate under water where o2 present only in low concentrations. In absence of O2, anaerobic respiration enables the rice seeds to germinate. The influence of CO2, CO, N2 and other gases in germination can be understood in terms of their effects on metabolic process. The effects are consistent with those noted concerning the need for O2 during cell division.

**4. Moisture**

Level of moisture of dry seed may be 5-12% which is insufficient for allowing rapid metabolism. So the first step in the germination is imbibitions through which the water content increase. As seed imbibes water, all the cells in embryo, cotyledons and endosperm becomes hydrated resulting in cell expansion and size increment. Water is essential for enzyme activation, thus permitting breakdown, translocation and use of reserve storage materials. Field capacity moisture level is optimum for germination and extreme moisture may inhibit germination. However, germination often proceeds at soil moistures near the permanent wilting point. The initial stage may even proceed under water available through high humidity conditions, although such conditions are not adequate for complete germination. Corn seed begins to germinate at moisture.

**5. Reserved food materials**

Seed contain stored food materials like CHO, proteins and lipids. If these are not accumulated

appropriate amount in the seed, it may not be germinate.

**6. Dormancy or resting period**

Many angiospermic seeds can’t germinate immediately after maturity even if provided with all

Favorable environments for germination. This condition is known as seed dormancy, which may not be germinated immediately after maturity because of immature embryo. After seed maturity, a rest period is necessary to develop embryo after harvesting. This period is known as after ripening period or resting period. Dormancy in seed is either due to embryo condition (immature embryo or need for after ripening) or due to seed coat (impermeable to water, gases or mechanical resistance).

**Longevity or viability of seed**

Longevity is the length of time that embryo retain their viability. Seeds retain their viability for certain period of time, after which the embryo becomes dead. Storage conditions and circumstances in which the seed mature often determine the period of viability. Non-viable seeds cannot germinate.

**8. Agronomic factors**

Defective crop husbandry during crop maturity and biotic and abiotic stresses during seed setting and maturity due to natural disruption in environmental condition affects seed viability and germination capacity. Cloudy days during grain filling produce chaffy non-viable rice seeds. Inadequate plant protection during fruit ripening may cause total loss of seed germination. Mechanical injury to seed due to rough handling during production, harvest and packaging may cause about 20-30% loss in germination.

**CHAPTER FIVE:**

**SEED QUALITY TESTING**

**1.** International seed testing association (ISTA) in 1924. Two the for most Achievements of ISTA,

* The adoption of the international rules for seed testing.
* The introduction of the international seed analysis certificate (documentation), widely used in the international seed trade and market.

**2.** Association of official seed analysis (AOSA) 1908

* 1908-Aosa of north America
* 1939- the phrases; the phrase of north America was dropped

Basic objectives of above ISTA and AOSA were;

* To develop, adopt ,and publish rules for testing seeds and
* To encourage research in seed technology.

The science of seed testing that is the science of evaluating the planting value of seeds has been developed to achieve the following objectives for minimizing the risks of planting low quality seeds.

* To determine their quality, that is their suitability for planting.
* To identify seed quality problems and probable causes.
* To determine the need for drying, processing and specific procedures that should be used.
* To determine if seeds meets established quality standards or labeling specifications.
* To establish quality and provide a basis for price and consumer discrimination among lots in the market.

**5.1. Seed sampling**

Sample is obtained from a seed lot by taking small portions of random from different stocks or portions at the time of processing or sealed bags in the lot and combining them. To have reliable estimate of the seed quality parameters, the representative sample has to be taken. Seed sampling is; very important, the procedure is very simple and the most used part of seed testing. The primary objective of sampling is; to obtain the sample of size suitable for tests in which the same constituents are present as in the seed lot. Therefore sample sent for analysis should truly represent the bulk of the seed to be tested. The proper sampling is the true picture of seed quality.

**Notice:** Seed lot means is a specified quantity of seed that is physically and uniquely identifiable. The following are such part of seed sampling.

* Primary sample –is a portion taken from the seed lot during one single action.
* Composite sample- is formed from by combining and mixing all the primary samples taken from the seed lot.
* Submitted sample- is a sample that is to be submitted to the seed testing laboratory and may comprise ether the whole of composite sample or by reducing the composite in such component.
* Working sample- this just the sample in the laboratory and obtained by dividing the submitted sample.

**5.1.1. General Principles of Seed Sampling**

1. Sampling should be carried out only by persons trained and experienced in seed sampling and employed by the official organizations.

2. The seed lot shall be so arranged that each individual container or part of the lot is conveniently accessible.

3. The size of the seed lot should also not exceed maximum seed lot size limits prescribed.

4. When sampling is being done by hand, great care should be taken to keep the fingers tightly closed around the seeds so that none may escape.

5. Other things being equal, a large sample is more representative of a lot than is a small sample.

6. The sampler should determine that all seed bags sampled are identified as belonging to a single lot, either by a label or template mark on the bag.

7. The sampler must sample the minimum requisite number of bags from the seed lot. The sampling intensity must not be less than that prescribed below.

**Sampling intensity**

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**5.2. Seed purity testing**

Objectives of seed purity test;

1. To determine the composition by weights of the sample being tested and by interpretation the composition of the seed lot.
2. To determine the identity of the various species of seeds and inert mater particles, consisting the sample, this means that all seeds and other particles not only have to be separated from the good crop seed and determined by weight basis.

**Analysis of purity components;**

The working samples are divided into different components of purity such as pure seed, other crop seeds, weed seeds and inert mater with the help of purity work board spatula and magnifying glass.

**AOSA purity test;** this test determines the percentage by weight of pure seed, other crop seed, inert mater and weed seeds in a test sample.

**ISTA Purity test;** this test determines the percentage by weight of pure seed, other seeds and inert mater. In the case of ISTA rule weed seeds may not considered as purity test component but each of other seeds and inert mater needed to be identified and named, then reported. The followings are the components of the sampled seed when seed experts going to made purity test.

**1. Pure seed-** refers to the species which is stated by the sender to be, in or found to be dominant in the seed lot.

* Such seeds are immature, undersized, shriveled/wrinkled, disease or germinated seeds unless transformed to fugal sceloratia, smut balls nematode gall are regarded as pure seed.
* Pure seed must include all botanical varieties and cultivars of that species.

**2. Inert mater-** inert mater includes such seed or seed like structure as pieces of broken or damaged seed empty glumes or any other extraneous mater such as soil, sand stone, chaff, stems, leaves, pieces of bark, flowers, nematode galls, fungal bodies and insect larva etc...

**3. Other crop seeds –** refers to any kind of seed and seed like structure of any plant species other than that of pure seed.

**4. Weed seeds –** Seeds, bulbils or tubers of plants recognized as weed by laws of official regulation or by general usage can be considered as weed seeds.

* Legume seeds usually break along the line of cleavage between the cotyledons. All cracked seeds are regarded as pure seed. If the seed or fragment of seed consists of larger than one half their original size considered as a weed seed.
* If one half or larger than one half consumed by an insect, it is considered as inert mater not a weed.

The percentage of each component should be reported as the sum of the individual components as a total not the original weight of the working sample. There shouldn’t be 5% variation between the original weight in percent and the weight after analysis of each component.

 Pure seed% = Weight of pure seed x 100

 Weight sum of all components

**Notice;** the percentage is in decimal it should be near to one or two place only.

**5.2.1. Moisture content**

Moisture content (M.C.) is crucial in connection with storage and longevity. Since moisture content of seeds tends to vary with atmospheric humidity, it is important that exposure to varying humidity is minimized before testing. Therefore, seeds should be packed in waterproof material as quickly as possible after sampling. In order to avoid the possibility of water condensing on the seed when removed from cold store, seed should be allowed to reach ambient temperature before the container is opened. Under laboratory testing, seed moisture is measured by the oven-drying method, which is the **direct** method, prescribed by ISTA. This method can also be used for calibrating moisture meters for **indirect** measurement of moisture content. The indirect methods provide very quick results, which can be used as a guide during seed handling, e.g. to determine the necessity for further drying.

Moisture content of a sample is the loss of weight when it is dried in accordance with the prescribed rules. It is expressed as a percentage of the weight of the original sample (ISTA 1996).

**Moisture content measurement contains the following components:**

1. Container (heat resistant) including cover is weighed (M1).

2. Seeds are ground or cut into smaller fractions before drying to assure that moisture can escape from the interior.

3. The seeds are placed in the container and weighed together with the container (M2).

4. Seeds are placed in an oven at 103 +/- 3°C for 17 +/- 1 hour.

5. After drying, the seeds are placed in a desiccation chamber while cooling (to avoid reabsorption of moisture from the atmosphere).

6. After cooling, the seeds plus container are weighed again (M3).

 The moisture content (M.C) = (M2-M3) x 100

 (M2-M1)

Seeds typically contain far less moisture in the seed-coat and possibly pericarp than in the embryo and endosperm. Hence, processing may influence moisture content both directly in terms of drying rate, and indirectly in connection with extraction and possible. The method anticipates that the total loss of weight is caused by evaporation of water. In practice other volatile compounds such as oil and resin are also lost during drying which, in seeds rich in these compounds, contribute to an overestimation of the moisture content. Despite this potential source of error, the oven-drying method is still used as a standard for these seeds, but the seed handler should be aware of the likely overestimation of the real moisture content when testing oil or resin rich seeds.

**5.2.2. Seed Germination Test**

During germination tests, seed quality is measured directly as the ability of the seed to germinate under optimal germination conditions of temperature, moisture and light. It is anticipated that germination is not hindered or delayed by possible dormancy. Therefore seeds should be pretreated before a germination test. Germination under the ISTA standard test is subject to strict prescriptions to pretreatment methods and germination conditions (ISTA 1996).Germination is normally carried out in germination cabinets under controlled environment. The conditions prescribed by ISTA include the following variables:

* Temperature (level and regime, e.g. constant day and night or fluctuating)
* Light (+/- light or period of day/night cycles).
* Substrate (sand (S), top of sand (TS), top of paper (TP), between paper (BT) and pleated paper.

Germinated seeds are counted regularly during the prescribed germination period from the indicated ‘first count’ to ‘final count’. Counting once per week is usually sufficient, but species with rapid germination may be counted and removed every two days. Removal of germinants is done in order to facilitate subsequent counting and to avoid possible fungal spread. Both ‘normal’ and ‘abnormal’ germinates are counted, registered and removed during the period. At the end of the period all ungerminated seeds are examined. The final test result is grouped into the following classes:

**1. Normal germinates:** The cumulative number of seeds which have developed into seedlings of normal and healthy appearance with all essential structures of a seedling. This also includes seedlings where possible damage is caused by secondary infection.

**2. Abnormal germinates:** The cumulative number of seeds which have germinated during the test period but in which the seedlings show abnormal or unhealthy appearance e.g. lacking essential structures such as cotyledons, or being discolored or infected by seed-borne pathogens (primary infection).

**3. Ungerminated seeds:** Seeds which have not germinated by the end of the test period. These are grouped into the following sub-classes:

**a. Hard seeds:** Seeds that remains hard because they have not imbibed (normally because of insufficient pretreatment).

**b. Fresh seeds:** Seeds that have not germinated although they appear firm and healthy.

**c. Dead seeds:** Seeds that are soft, or showing other signs of decomposition.

**D. Other seeds**: E.g. empty seeds.

Category a. and b. may be germinable but dormant. Their correct status may be further determined by viability test. If the number of viable but not germinated seeds is high, a new germination test following new pretreatment may be appropriate. The final evaluation of the germination test is reported as germination percentage or germination capacity, which counts ‘normal germinants’.

**5.2.3. Seed vigor**

**5.2.3.1. The concepts of seed viability and seed vigor**

Standard germination test is an indicator of seed quality, which can be used to predict the field emergence, if soil conditions are nearly ideal (best). Field germination depends on seed viability. Seed viability or seed vigor are the set of characteristics that determine the activity and behavior of the seed lots of commercially acceptable seed germination in different environmental conditions.

In addition to the above mentioned, longevity of the seed is determined by the seed vigor without adverse consequence. To obtain more precise information about the quality of the seed lot different vigor tests are used.

The term vigor or viability is used to describe the physiological characteristics of seeds that control its ability to germinate rapidly in the soil and to tolerate various, mostly negative environmental factors. Results of vigor tests can be used in deciding whether the seed lots can be sown earlier in the season, when the occurrence of stressful conditions is possible, or it should be sown later, when the soil is warmer and the conditions become more favorable for germination and seedling growth.

**5.2.3.1. Importance of seed vigor testing**

Vigor testing does not only measure the percentage of viable seed in a sample, it also reflects the ability of those seeds to produce normal seedlings under less than optimum or adverse growing conditions similar to those which may occur in the field. Seeds may be classified as viable in a germination test which provides optimum temperature, moisture and light conditions to the growing seedlings; however, they may not be capable of continuing growth and completing their life cycle under a wide range of field conditions. Generally, seeds start to lose vigor before they lose their ability to germinate; therefore vigor testing is an important practice in seed production programs. Testing for vigor becomes more important for carryover seeds, especially if seeds were stored under unknown conditions or under unfavorable storage conditions. Seed vigor testing is also used as indicator of the storage potential of a seed lot and in ranking various seed lots with different qualities.

**5.2.3.2. The biological basis of the seed vigor concept**

It has been established that the conditions of seed development, maturation, storage and aging influence seed vigor. Seeds developed under moisture stress, nutrient deficiency, extreme temperatures, etc... Often result in light, shriveled seed or collectively called poor-vigor seed. Preharvest environment of high humidity and warm temperatures can also cause loss in seed viability and vigor. Seed mechanical damage, whether induced by harvesting or conditioning equipment, as well as improper storage conditions are among the factors that adversely affect seed vigor. In addition, genetic factors such as hard seediness and resistance to diseases influence the expression of seed vigor.

**5.2.3.3. Methods of measuring seed vigor and viability**

The general strategy of determining seed vigor is to measure some aspects of seed deterioration or a weakness. Cold test, accelerated aging test, electric conductivity test, seedling vigor classification, and seedling growth rate are among the tests that are used to measure seed vigor.

**5.2.4. Seed Viability Test**

**Tetrazolium test:** Tetrazolium test was developed in 1950 as a test for obtaining rapid general estimation of seed viability, particularly in species in which dormancy was expressed, and germination test would too long. This test is widely applied;

* When sowing must be performed immediately after harvest in very dormant seed,
* In slowly germinated seed,
* When information on potential seed germiability is needed straight away,
* In order to determine different types of damage caused by harvest or processing (heat, mechanical or damage caused by insects),

Tetrazolium test is based on reduction of colorless solution 2, 3, 5 – tripheniltetrazolim chloride or bromide into insoluble 2, 3, 5- triphenilformazan red in color. This solution acts as an indicator for detection of reduction processes that take place in living parts of the seed. Inside the seed, tetrazolim intakes hydrogen from dehydrogenase reaction. By hidrogenization of tetrazolium a red, stable substance called formazan, which dyes living parts of the seed, is formed in the living cells. Seed is submerged in water because swollen seed is hard to crack and easy to cut in relation to dry seed and dying is more uniform. Tissue of many plant species must be removed to introduce the dye into the tissue.

Tissue removal can be done by pilling the seed coat off, punching, and longitudinal or cross-cutting of unessential seed parts. Prepared seed is submerged into 0.5 – 1% tetrazolium solution. Seed must be completely covered with solution, and not exposed to direct light. After the time needed for dyeing expires (it depends on plant species) the estimation of dyeing is approached. During testing the viable seed should express its potential for normal seedling formation through biochemical activity. Non-viable seed expresses malformations which prevent normal seedling formation. All tissue (necessary for normal seedling development) of a viable seed should be dyed. Except completely dyed, viable seeds, and completely undyed (purple or white), unviable seeds, a partly dyed seeds may also be found. Depending on the species, small undyed spots of some parts of these tissues may be accepted. Location, size of undyed areas, and sometimes intensity of dyeing, determine whether some seed is considered as viable or not.

**Tetrazolium test has several limitations because it:**

* It cannot be separated seed which will give typical and abnormal seedlings before seedlings are germinated.
* Causes difficulties in the visual identification of abnormal seedling (i.e. split coleoptiles, negative geotropism etc.).
* Requires specially trained personnel and,
* Does not detect the presence of pathogen or phototoxic effect.

**5.2.5. Seed health**

Components of seed quality can be grouped into three categories:

**1.** Description: species and cultivar purity; analytical purity; seed weight.

**2.** Potential performance: germination; vigor; moisture content; field emergence and uniformity storability

**3.** Hygiene: noxious weed contamination; seed health (e.g. storage fungi contamination); insect.

 **Seed infection mechanisms; there are two mechanisms;**

1. Systemic infection of the seed: the establishment of a pathogen in any part of a seed is referred to as seed infection. It can be systemic by the vascular system or by natural or artificial wounds. Natural openings like the hilum and the micropyle or wounds generating during the thresh are spots where pathogens like *xanthomonas campestris* in bean and *pseudomonas* in cucumber.
2. Seed contamination or infestation; it refers to the passive relationship of a pathogen and a seed. The pathogen itself or parts can stick or mixed with the seeds during in any of the process like harvesting, extraction thresh, packing etc....
3. Pathogens that stick to the surface of the seed; pathogens that stick to the seed during at harvest or post-harvest do so by their spores (*clamidospores, Oospores, Teliospores, uredo spores*), bacterial cells and in some cases virions.
4. Accompanying contamination; this type of infection refers to physical mixing of the seed with pathogens propagation organs like, the sclerotium, nematodes galls, contaminated plant parts or soil particles containing pathogens.
5. Seed transmition in general terms infection can be classified into systemic and non-systemic, when it is systemic the pathogen introduces itself to the plant when the seed germinates and develops with it. Non systemic infection occurs when there is a localized infection caused by the pathogen in the seedling at the stage of pre or post emergency.

**Prevention of seed borne disease:** prevention might be performed into two ways,

* On one hand there is the usage of material free from pathogens that could be originating the disease.
* On the other hand there are the treatments to eliminate the inoculum in the seed.

**Generally quality means:**

* Is high in species, varietal and physical purity;
* Has high germination and vigor;
* Is free from weeds and seed borne disease;
* Has low physiological moisture content;
* Is uniform and is properly processed for distribution to farmers.

**Chapter Six:**

**Seed Enhancement**

**Seed enhancement** is a range of treatments of seeds that improves their performance after harvesting and conditioned, but before they are sown. They include priming, steeping, hardening, pregermination, pelleting, encrusting (coating), and others. They are used to improve seed sowing, germination and seedling growth by altering seed vigor and/or the physiological state of the seed. The alteration may improve vigor or the physiological state of the seed by enhancing uniformity of germination. Treatments may include **hydration treatments**, such as priming, steeping, hardening, and pre-germination. **Other treatment** includes the use of chemicals that improves stress tolerance of a certain crop seed. The use of **antioxidants** enhancements like pelleting, coating and encrusting improve seed handling and planting. Some treatments enhance nutrient availability or provide inoculates by delivering materials other than pesticides needed.

These treatments are used to make germination and seedling growth more rapid and synchronous in the seedbed in the open field or in protected conditions, and better tolerate environmental stresses. Both priming and coating technologies can also deliver beneficial microorganisms from seeds to crops. Organic farming market standards are stimulating the evaluation and optimization of methods to produce healthy planting material and new seed sanitation treatments as alternatives to fungicides or conventional hot water or bleach treatment while retaining seed viability in storage.

**Seed hardening -** It is a process or treatment by which plants growing from the hardened seeds are capable of withstanding soil moisture stress. Seeds are soaked in 2% potassium dihydrogen phosphate solution for 10 hrs and then dried back to original moisture. Instead of chemicals, botanicals like leaf extract can also be used for hardening purpose. One kg of seeds is to be soaked in 600 ml of leaf extract for 16 hours. Hardened seeds will have the ability to withstand drought during germination and plant growth.

**Seed enhancements-objectives**

* Improve germination**/**seedling growth through manipulation of seed vigor or physiological status.
* Hydration treatments (priming, steeping, hardening, pre-germination).
* Chemicals to activate systemic acquired resistance (SAR) or stress tolerance.
* Antioxidants.
* Facilitate seed planting (pelleting, coating, and encrusting).
* Deliver materials (other than pesticides) needed at sowing (e.g. nutrients, inoculants).
* Remove weak or dead seeds using non- traditional ‘upgrading’ techniques (color, sorting, and x-ray).
* ‘Tagging’ of seeds with visible pigments or other materials/markers for traceability and identity preservation.
* Most are used extensively in high- value, low-volume hort/ornamental crops.
* Film (loose) coating also widely used in higher- value, high volume agronomic species (e.g. cotton, maize and sunflower).
* Use of coatings well established in small-seeded legumes and some turf species.

**Seed priming**

* A broad term in seed technology, describing methods of physiological enhancement of seed performance through pre- sowing and controlled-hydration methodologies.
* Seed priming also describes the biological processes that occur during these treatments.
* Improvements in germination speed and/or uniformity common with primed seed lots.
* Priming in botany and agriculture is a form of seed planting preparation in which the seeds are pre-soaked before planting.
* Seed priming is a technique of controlled hydration (soaking in water) and drying that result in more rapid germination when the seeds are re-imbibed.

**Seed Steeping**

* Steeping is placing of a seed in moisture mulch or any other material so as to soften the seed coat of it.

**Pelleted seeds**: Covering of the seed by any material that is compatible with the seed.

* Seeds that have been coated with an inert material just to make the handling of the seed easier.
* Pelleted seed is covered with a soluble coating that makes it easy to handle and space out evenly.
* Seed coating is a thicker form of covering of seed and may contain fertilizer, growth promoters and or seed treatment as well as an inert carrier and a polymer outer shell.
* Seed coating is the addition of chemicals to protect the seed from external damage or improve the germination with a film of external chemicals.

**CHAPTER SEVEN:**

**GENERAL PRINCIPLES OF SEED PRODUCTION AND MAINTENANCE**

**7.1. Principles of seed production**

The seed production is aimed at getting high yield of genetically pure and good quality seed. Production of genetically pure and good quality seed is an important task requiring high technical skills and comparatively heavy financial investment. Quality seed production is not like general seed production. We must have to follow scientific principles to get quality seed.

**A) Genetic principles**

The genetic purity (trueness to type) of a variety can be deteriorating due to several factors during production period. The best method for the maintenance of genetic purity of any seed is to overcome the greatest possible factors which are responsible for genetic deterioration. Mostly the genetic deterioration in seed may take place due to:

**1.** Developmental variations

**2.** Mechanical mixture

**3.** Mutations

**4.** Natural crossings

**5.** Minor genetic variations

**6.** Selective influence of diseases

**7.** The technique of the plant breeder.

**1. Developmental variations**

When the seed crops are grown in different environment under different soil and fertility conditions, different climatic conditions, under different photoperiods or at different elevations for several consecutive generations, the developmental variations may arise. Therefore to minimize the developmental variations it is advisable to grow these varieties in their areas of adaptations and growing areas.

**2. Mechanical mixture**

It is most important source of variety deterioration during seed production. It may often take place at the time of sowing (if more than one variety is sown with same seed drill), through volunteer plants of the same crops in the field or through different varieties grown in adjacent fields. If two varieties are growing alongside each other in the field, they often mixed during harvesting and threshing. Keeping of all varieties grown often in the same threshing floor results in varietal mixtures. Threshing machine is often contaminated with other varieties in augers, elevators, etc. Similarly, the gunny bags, seed bins, elevators are also quite often contaminated with seeds of other varieties. To avoid this sort of contamination, it would be necessary to rogue the seed field and practice utmost care during seed production, harvesting, threshing and handling.

**3. Mutations**

It is not a serious factor of varietal deterioration. In the majority of the cases it is difficult to identify minor mutations.

**4. Natural crossing**

 It is also another important source of varietal deterioration in sexually propagated crops which is due to introgression to genes from unrelated stocks and can be solved by prevention. The extent of varietal contamination depends upon the amount of natural cross fertilization. The deterioration of varieties due to natural crossing occurs by crossing with undesirable types of plants, crossing with diseased plants and with off type plants. Natural crossing is not serious of contamination and variety deterioration in predominantly self fertilized crops unless the varieties are male sterile and is grown in close proximity to other varieties. It is major source of genetic contamination and variety deterioration in cross-fertilized or often cross-fertilized crops. Extent of genetic contamination in seed fields due to natural crossing depends upon (Bateman, 1947):

* Breeding system of species
* Isolation distance
* Varietal mass
* Pollinating agent

The extent of contamination depends upon the direction of prevailing wind, number of insects present and their activity, humidity and temperature at the time of anthesis, etc. Isolation of seed crops and periodic rouging are the important methods to minimize the problems of natural crossing.

**5. Minor genetic variations**

Minor genetic variations may still exist even in the varieties appearing phenotypically uniform and homogenous at the time of their release. During later production cycle some of these variations may be lost because of selective elimination by the environment. It is constant feature in often cross pollinated crop species therefore care during maintenance of nucleus and breeder's seed is necessary in such cases.

**6. Selective influence of diseases**

It is also an important factor for seed purity deterioration in new crop varieties. New varieties often become susceptible to new races of diseases often caused by obligate parasites and are out of seed programs. Similarly, the vegetatively propagated stocks deteriorate fast if infected by viral, fungal and bacterial diseases.

**7. Techniques of plant breeders**

In certain cases, the serious instability may occur in varieties due to cytological irregularities not

Properly assessed in the new varieties prior to their release. Premature release of varieties, still

Segregating for resistance and susceptibility to disease or other factors may also important in the

deterioration of varieties.

**Methods of maintaining genetic purity in the seed crops**

**1.** Use of approved seed only in seed multiplication – breeder, foundation, certified, registered.

**2.** Inspection and approval of fields prior to planting.

**3.** Provide adequate isolation distance to prevent natural crossing and mechanical mixture.

**4.** Regular rouging operation should be followed in the seed plot prior to the stage at which they

 Could contaminate the seed crop.

**5.** Periodically varietal testing (grow-out test) should be done for genetic purity.

**6.** Seed should be certified by certifying agencies to maintain genetic purity and quality of seed.

**7.** Avoid genetic shift by growing crops in areas of their adaptation only.

**8.** Inspection of field is done at critical stages for verification of genetic purity, detection of

 Mixtures, weeds and for freedom from noxious weeds and seed borne diseases.

**9.** Use the approved seeds only in seed multiplication program.

**10.** Adopting the generation system.

**B) Agronomic principles**

Besides the genetic principles for standardized seed production, the application of the following

Agronomic principles should also be followed.

**1. Selection of suitable agro-climatic region**

A crop variety to be grown for seed production in an area must be adopted to photoperiodic and

Temperature conditions prevailing in that area. In general suitable agro-climate for seed production is the region where there is ample sunshine, relatively moderate rainfall and the absence of strong wind. Most crops require a dry sunny period and moderate temperature for flowering and pollination. Excessive dew and rain causes hindrance in normal pollination resulting in poor seed set, higher incidence of pest and diseases, delay maturity, reduces the quality and quantity of the seed cause sprouting of the seed on the plant. Similarly too high temperatures causes desiccation of pollen resulting in poor seed set and very cold temperatures bring in another injury and collapse of the embryo sac.

**2. Selection of field and its preparation**

Proper field selection is important for successful production of almost any crop; however, it is

Particularly important for seed production. The field selected for seed crop must be fertile and able to fulfill the requirement of the crop. The seed plot should be free from volunteer plants, weed plants and other crop plants. The soil of the seed plot should be comparatively free from soil-borne diseases and insect pests. In the preceding season the same crop should have not been grown on this land if it is so required by the seed certification standard. Fields that has produced seed crops of small-seeded forage legume (e.g., red clover) should not be used to produce seed of another inseparable legume seed crop (e.g., alfalfa). Seed of such crops tends to remain viable in the soil and continue to germinate and contaminate subsequent crops. The field preparation consists of eliminating weeds or other crops and preparing a favorable seedbed. Most seed crops are planted by conventional methods following the preparation of a fine, well-tilled seedbed that helps to achieve maximum seed-soil contact. The seed plot must be leveled. Soil showing symptoms of salinity and alkalinity are not desirable. Soil where water tend to log or stagnate should be avoided. The land of the seed crop must be prepared well. This will help in improved germination, destruction of potential weeds, water management and uniform irrigation.

**3. Selection of variety**

The variety for seed production must be carefully selected. The variety should be very popular with the farmers and adapted to agro-climatic condition of the region. The variety should be really high yielder. It should posses other desirable attributes like disease resistance, earliness, grain quality etc.

**4. Selection of seed**

The seed used for raising a seed crop should be known purity, appropriate class and obtained from an authorized official agency. The tag and seals of the breeders or foundation seed bags must be intact. The validity period has not expired and all the bags are of the same variety.

**5. Isolation of seed crops**

The seed crop must be isolated from other nearby fields of the same crop and other contaminating crops as per requirements of certification standards Isolation is obtained by providing distance between seed field and contamination field. In some crops time isolation can be followed by adjusting the date of sowing in such a way that flowering does not coincide with one another.

**6. Seed treatment**

The seed generally given by authorized official agency is already treated, if seed is not treated then we should treat the seed. There are three types of seed treatments followed for different purposes:

**a)** Chemical treatment to control insects and diseases infestation.

**b)** Legume seed inoculation to increase N assimilation from the atmosphere.

**c)** Seed treatment to break dormancy

**7. Time and method of planting**

Seed crop should be sown at their normal time of planting. Sometimes we can do some adjustments to escape from certain diseases and pests. At the time of planting there should be sufficient soil moisture for germination. Seed drill or planters preferably do seed sowing. They should be used after thoroughly cleaning to avoid mechanical mixture of the seed. Seed should have to sown in lines so that plant protection measures, rouging operation and crop inspection can be conducted quite effectively.

**8. Nutrition of the seed crop**

It is well known fact that adequate fertilizer should be applied to get maximum yield of good quality seed. The amount of fertilizer to be applied to seed crop will depend upon various factors like fertility status of soil, previous application of organic manure and the requirement of the crop. In general following point must be considered:

**i.** The fertilizer should be applied according to recommendation given to individual crop.

**ii.** All fertilizer especially N, P and K must be applied in balanced form.

**iii.** Nitrogenous fertilizer should be applied in split dose as per recommendation given for

 Individual crop.

**iv.** If soil is deficient in micro-nutrients then we must be use micro-nutrients as per requirement of crop.

**v.** In case of starchy crop like potato, sugarcane etc we must be used sufficient amount of

 Potassium fertilizer.

**vi.** Do not use of excess of N as it may be deleterious to certain seed crop. It may cause delay

 maturity, succulence, lodging of the crop.

**vii.** In case of oil seed crop use of sulphur containing fertilizer may be useful. If available better

 use ammonium sulphate instead of urea.

**9. Seed rate**

Lower seed rates than usual for raising commercial crops are desirable because they facilitate rouging operations and inspection of seed crops.

**10. Depth of sowing**

Depth of sowing is extremely important in securing good plant stands. Small seeds should usually be planted shallow but large seed could be planted litter deeper. Seeds would emerge from greater depths in sandy soil than in clay soils also in warm soil as compared to cold. In dry soils, seed should be planted slightly deeper so that they come in contact with moisture.

**11. Weed control**

Weed may cause contamination of the seed crop due to which at the time ofharvest leads to mixing of weed seeds with crop seed. The presence of weeds in the seed field or nearby areas may serve as a host to number of diseases. The following measures should be followed to control weeds during seed production.

**a)** Use clean and stale seedbed

**b)** Follow a good crop rotation

**c)** Provide intercultural operation and weeding practices as per requirement of crop

**d)** Use of suitable herbicide at right time and right dose as per crop requirement

**12. Irrigation to seed crop**

Seed crop should be grown in the regions having moderate rainfall. In such regions irrigation is

Essential to obtain good seed yield. Excess water or prolonged drought adversely affects the germination and stand resulting in poor seed yield. In general irrigation should be given as per requirement of crop. Lighter soil needs more irrigation than heavier soil. Excess soil moisture at any time may be harmful for seed production. It is essential to stop irrigation at least two weeks before harvesting. It helps in uniform maturity of crop as well as easy harvesting.

**13. Pollination control**

Seed production of any crop requires the fertilization of the female gamete of the flower with a male gamete from the pollen grain. This fertilization occurs during anthesis, defined as the time that flowers have formed and the stigma is receptive to pollen. Cross-pollinated crops depend on either wind or insects to bring pollen in contact with the stigma. Although both processes occur naturally without human assistance, insect pollination can be greatly aided by the seed producer. Insect pollination occurs when the insect is attracted to the flower in its search for either nectar or pollen. During its activity in the flower, pollen from previously visited flowers adhering to various body parts is rubbed off onto the sticky stigma. Although many types of insects are effective in pollination, various kinds of bees are especially common and effective. As a result, successful seed producers bring in colonies of honeybees and culture wild bees to aid in the pollination of seed crops. Aiding insect pollination is often the key to success and is an important part of seed production of many insect pollinated species.

**14. Field inspection**

A minimum of 2 inspections should be conducted. The first inspection is conducted at flowering to verify source of seed used for seed production and to check isolation requirements. The final inspection is allowed with the request of seed grower, if the number of off types and objectionable weed plants exceed prescribed permissible limit. During final inspection at maturity of seed crop, actual counts are taken from separate places distributed at random in such a way that whole area of the seed plot is covered.

**15. Rouging**

Rouging are plants, which differ from normal plant population. Rogue may be weak plant, diseased plant, dissimilar plant in colour, height, tillering behaviour, leaf orientation, leaf size, auricle colour, flowering, maturity etc. If there are plants of UP-262 wheat variety in the seed crop of NL-297, than these are called off type. If there is wild oat (*Avena fatua*) in the seed crop of wheat field, then it is also called rogue. Generally rouging is done at vegetative or pre flowering stage, flowering stage and maturity stage.

**16. Plant protection**

Successful disease and insects control is another important factor in raising healthy seed crops. Apart from reduction of yield, the quality of seed from diseased and insect damaged plants is invariably poor. Therefore, preventive and curative methods should be followed to produce high quality seed which is free from insect, pest and diseases.

**17. Harvesting of seed crop**

It is of great importance to harvest a seed crop at the time that will allow both maximum yield and the best quality seed. The following points should be considered before harvest:

a) Seed is fully mature.

b) Weather damage has not started.

c) Seed can be easily harvested and cleaned.

d) There will be minimum harvest losses.

Harvesting at early stage makes combine harvesting difficult and relative losses due to threshing and cleaning are greater. Harvesting at a late stage may result in increased weather damage to seeds and losses due to shattering of seeds and lodging of plants in the field. The moisture content is a good indication of the optimum time to harvest of most seed crops. Combine harvester do not operate well above 15% seed moisture. For wheat the optimum moisture content is 15-17% at the time of harvesting where as maize ears are picked up even at as high as 30-35% moisture content.

**18. Drying of seeds**

The seed lots usually are at high moisture content at the time of harvesting and threshing. In order to preserve seed viability and vigour it is necessary to dry seeds to safe moisture content levels.

|  |  |
| --- | --- |
| **Moisture content (%)** | **Storage life** |
| 11-13 |  6 months |
| 10-12 | 1 year |
| 9-11 | 2 years |
| 8-10 | 4 years |

 Note: temperature not exceeding 32 C0

**Precaution to be taken during drying:**

Care should be taken to ensure that mechanical mixture does not take place. Identity of the lots must be maintained. If the seeds are to be artificially dried they should be supplied to processing plants soon after harvesting. If seeds are to be dried on farm it must be spread thinly over cement floor or in tarpaulins.

**19. Storage of seed**

From the moment of maturity until planting, the seed is stored either on the plant or in the seed store. By using proper storage condition, the rate of seed deterioration can be greatly slowed. According to an estimate about 6-7% of the post harvest losses are in storage itself. Seed deterioration occurs in storage due to respiration and heating, micro-organism, insects and rodents and biochemical changes. Two simple rules say that for every one percent decreases in moisture content storage life of the seed is doubled and for every 5 C0 decrease in storage temperature, the storage life is also doubled. The ideal temperature range for insect and fungal activity is 21 C0 to 27 C0. Therefore the storage temperature as much colder than 21C0 as possible is required for long-term seed storage. The godowns (Warehouse) to be used for storage of seed should be dry, cool and clean and sprayed with Malathion and later fumigated as and when necessary. The best method of storing seed for short periods is in sacks or bags in godowns. The entire bag must clean and treated with insecticides. There are chances of mechanical mixture from bags, so proper care should be taken while putting the seed in the bag. The name of variety, lot number of seeds must be written on bags for identification and further handling of the seed. The bag should not be kept just on the ground but it should be kept on wooden pallets. The height of sacks should not be more than 3m to 4m in the case of cereals and 2.5m to 3m for other crops.

**20. Seed packaging**

Seeds are commonly packed in cotton, jute and paper bags. These materials offer no protection against high relative humidity. Under high humidity locations with inadequate seed storage conditions, vapour proof containers can be used. Polythene bags have been regarded as suitable looking to its cost and easy handling.

**CHAPTER EIGHT:**

**SEED QUALITY CONTROL**

Quality control is an important component of the seed programme. In fact the essence of any seed programme lies in the quality control. A seed programme without the provisions of regulating the seed quality control measures may collapse. Seed quality control is a system which ensures to govern the quality of the seed through check, certification and official regulations (legislation). For seed production, it is necessary that the quality of the seed should be of the highest possible standards. Quality of seed is ensured and guaranteed through checks i.e. field inspections to establish genetic/varietal purity and laboratory tests to record physical purity, germination, vigor, moisture content and seed health.

**Seed quality control concepts**

There are two aspects of quality control. Firstly, the genetic purity of the seed is maintained during the production and marketing operations. Secondly, it should be ascertained that the seed lot itself is of adequate quality. It should be free from weeds, other crop seeds, extraneous materials, disease organisms and possesses high germination capacity and optimum moisture to avoid its deterioration during storage and marketing. There are three important facts to achieve the above objectives. These are:

**1.** Quality maintenance

**2.** Quality assurance

**3.** System of quality control

**Quality maintenance**

The responsibility of maintaining the quality of the seed lies with the producer (public or private) who is producing and marketing the seeds. Seed production is a highly specialized and systematic job. It encompasses the production of nucleus seed, breeder seed, foundation, certified and labeled seed classes. The process occurs in systematic manner. The breeder seed is produced from nucleus seed; foundation seed from the breeder seed or foundation stage 1 and the certified seed from foundation seed or certified stage 1 classes. If there is some missing link in this chain, quality maintenance programme suffers and consequently the quality assurance and quality control components will get the set-backs. It is, therefore, imperative that adequate care needs to be exercised in the quality maintenance or internal quality control programme. If, this is achieved adequately well, the problems in the quality control will be minimized and the assurance of seed quality provided by the producer will not face any problem during marketing or distribution.

The first and foremost aspect of quality maintenance is the quality of the breeder seed with special reference to the genetic purity. Breeder seed should be of the highest genetic purity. The genetic purity of breeder seed should be above to the genetic purity status of the foundation seed class. Usually, the breeder seed does not falls under the preview of seed certification. However, its quality must be monitored by the breeder himself or by a joint team or any other authority which has been identified in the rules and regulations. In addition, it is also equally important that the post harvest operations should also be supervised to avoid contaminations during harvesting, threshing, drying, cleaning, grading and packing operations of the breeder seed. In case of vegetable seeds, seed certification is opted mainly by the public organizations, it would, therefore, be essential that the private seed companies should have their own research and developmental wing for ensuring the quality of their produce so as to serve the farmers in a better way.

**Quality assurance**

This is the responsibility of the seed corporation/organization and the seed companies to provide

Assurance about the quality of the seed offered by them for marketing or distribution. There would not be any problem to the seed producing organizations in providing the assurance of the seed quality, if they are conscious about the maintenance of the quality of their produce. In the absence of the system of quality maintenance, it would be rather impossible to provide the assurance of the seed quality. Without observing the quality maintenance, if quality assurance is provided by an organization in the form of a declaration or a label containing the details of the physical purity and germination of the seed, the organization may face heavy penalties under the provisions of the seed legislation or seed act or else will lose the faith of the consumer. Accordingly, it would be desirable on the part of an organization or seed company involved in the seed trade that before providing the assurance relating to the identity of the variety and the quality of the seed offered by them, they must ensure to get the seed tested in the seed testing laboratory.

**System of quality control**

Seed quality control is itself a system which ensures the interest of the farmers and to avoid hazards in the crop production. It is the responsibility of the government to enforce the measures for controlling the quality of the seed being marketed in the country. This is usually accomplished through the legislation in the form of a law or act of parliament. Essentially, there are two components in a seed quality control system namely: the seed certification and labeling. Seed certification may not be compulsory but labeling is usually compulsory provision of any seed legislation. To accomplish the task of seed legislation or seed act framing the rules and regulations pertaining the legislation and their scope is the pre-requisite. In addition, certain basic infrastructural facilities are also required. This includes, the notification of the seed standards, kind or varieties expected to be governed by the legislation, establishment of seed certification authority or agency, seed testing laboratories, processing plants and notification or authorization of seed inspectors and seed analysis.

**Essential of seed quality control**

The following are the essential components of a seed quality control programme:

**1.** Quality control of breeder seed

**2.** Seed certification

**3.** Seed legislation

**4.** Seed standards

**5.** Seed testing.

**TYPES OF SEED, THEIR PRODUCTION AND SEED STANDARDS**

The seeds are evolved, tested and if found good, they are multiplied and distributed to the farmers for commercial production of the crop. Therefore according to the nature and precautions with which the seeds are produced, they are classified into the following groups:

**a) Basic or Nucleus seed**

Basic or nucleus seed is the original or first seed (= propagating material) of a variety available with the producing breeder (= the breeder, who developed the variety in question) or any other recognized breeder of the crop. This seed has 100% genetic and physical purity along with high standards of all other quality parameters. Nucleus seed is multiplied and maintained by selecting individual pods/spikes/plants and growing individual pods/spike/plant progenies. This process is repeated continuously. Nucleus seed is divided into the following two sub-classes: nucleus seed stage I and nucleus seed stage II.

**b) Breeder seed**

Breeder seed is the progeny of nucleus seed and is the source for initial and recurring increase of

Foundation seed. Breeder seed is produced by the research institutes and agricultural universities under the supervision of plant breeder to provide genetically pure seed for foundation seed production. The production is directly controlled by the originating plant breeder who developed the variety or sponsored plant breeder. It is produced as a result of hybridization, selection and mutation. Breeder seed is genetically so pure as to guarantee that the subsequent seed class (foundation seed) shall conform to the prescribed standards of genetic purity. Other attributes of seed quality must meet the norms specified for the crop. The quality norms for breeder seed are indicated in the label attached to the seed bag. Breeder seed tag is golden yellow in color. Breeder seed may be divided into the following two groups: breeder seed stage I and breeder seed stage II. Breeder seed stage I is the progeny of nucleus seed, while stage II breeder seed is the progeny of stage I breeder seed. Breeder seed stage II is allowed only under the conditions when the breeder seed stage I is extremely short supply and it needs to be multiplied as breeder seed to continue the seed chain in an effective manner.

**c) Foundation seed**

Foundation seed is the progeny of breeder seed and it conforms to the prescribed field and seed

Standard. Foundation seed is second grade seed in order of its genetic purity because there may be slight degeneration during the process of multiplication of breeder seed. Production of foundation seed is done generally by government farm or by certain organizations. A strict seed plot technique, which includes inspection, rouging, weed control; isolation etc.. is adopted during seed production process. The foundation seed is relatively less pure compared to the breeder's seed. It has white tag and available in limited quantity. It can also be classified as foundation seed stage I and foundation seed stage II. When seed is the progeny of breeder seed, it is called foundation seed stage I, while it is called foundation seed stage II when it is the progeny of foundation seed stage I. foundation seed stage II shall not be used for further increase of the foundation seed. It should only be used for the production of certified seed class. The minimum seed standards for both foundation seed stage I and II are similar unless otherwise prescribed.

**d) Certified seed**

Certified seed is the progeny of foundation seed and its production is so handled as to maintain

Specified genetic identity and purity standards as prescribed for the crop being certified. Certified seed can also be the progeny of certified seed provided this reproduction does not exceed three generations beyond foundation seed stage I. certified seed produced from foundation seed is called certified seed stage I, while that produced by multiplication of certified seed itself is called certified seed stage II. Certified seed stage I seed is also produced in government farm or by certain organizations. During the period of seed production, the seed inspectors inspect the field and the seed thus produced is processed, bagged and tagged in the presence of the seed technicians of the seed-certifying agency. After proper leveling, the seed is sold to the leader farmers or certain organizations. It has tag with blue border. Certified seed stage II is produced in seed producing farmer’s field with the supervision of seed certifying agencies. It is relatively less pure compared to previous three seed categories. It has tag with green border. It is source seed for improved seed production. It is available in sufficient quantity.

**e) Improved/commercial seed**

Improved seed is the progeny of certified seed 2nd generation. It is produced in the farmers’ field with supervision of certifying agencies. They have a wide range of adaptability, tolerance to adverse environmental conditions such as drought, flood and frost. Their quality is acceptable to the local market and consumers. It is available in sufficient quantity. It has yellow tag and is used for commercial cultivation of crop.

**f) Other types of seeds in agronomic use**

**Hybrid seed**

Hybrid seed is the seed produced by hybridization i.e. by crossing between two or more homozygous inbred lines to obtain a desirable type having high yield potential. Only the F1 generation of hybrids is recommended for use as seed for commercial production. To obtain such F1 hybrid seeds parents are to be maintained and freshly bred each time particularly if the same vigour and known desired quantities are to be maintained. Hybrid seeds may be the product of single or double cross or multiple cross.

**Composite seed**

Composite seeds are produced by inter-crossing a number of selected varieties by making germplasm complexes. Such composites posses the genetic potential for high level of production and are comparatively more stable than hybrids. Thus they need not be replaced after F1 generation for commercial cultivation.

**CHAPTER NINE:**

 **SEED SUPPLY SYSTEM**

Seed is a vital input in crop production. Ever since seed was considered an important vehicle to extend intensified production techniques in developing countries, the supply system has received considerable attention. These formal systems, designed along the lines of western organization patterns of seed supply, have replaced the age-old local seed supply systems in particular regions and crops. Limitations of these systems have led to the development of the concept of integrated seed supply.

**9.1. Formal Seed Supply System**

**Formal seed system:** this is usually defined for an entire country and includes all the public and private commercial seed enterprises which contribute to the seed system. When fully developed, the formal system is highly structured, subject to legislation and to regulation, including control of varietal identity and the quality of traded seed. Varieties used in this system are usually the result of breeding programmes and have passed through formal testing procedures before being released for multiplication and marketing. In most developing countries, this system was introduced and developed by the government, with the financial assistance and guidance of externally-funded seed projects.

**9.2. Informal seed supply system**

**9.2.1. Local seed systems**

**Local seed systems:** these are traditional seed systems that developed naturally over time in response to farmers' demands for seed from sources other than their own farm. Recently, local seed systems have received support and encouragement from NGOs and development projects concerned with issues such as traditional farming systems, community participation in research and genetic conservation. Traditional local systems are characterized by a low level of organization and institutional development. They lack formal quality control and are not subject to seed trade regulation. Seed is multiplied without any generation control. Other than from their own farm, farmers usually obtain seed from neighbors or from local traders known to them. Recently developed local seed systems often are more structured and organized. They may have some features in common with the formal seed system and may depend on it for one or more inputs or operations. In the latter case, they may be partly subject to government regulation.

**9.3. Integrated Seed supply system**

**Integrated seed systems:** this refers to the concept of linking formal and informal seed systems, in which one or more components of one system also service another system. Low-input agriculture: this term is used here rather loosely to indicate farming systems with a sub-optimal production environment for a specific crop. It is not used as an indication of resource use per land and production unit. These environments are defined by agro ecological and climatologically constraints, or by farmers' management choices based on the cost/benefit ratios of labor or other inputs. A major factor distinguishing formal and local seed supplies is that the former is vertically organized, whereas the latter system can be considered horizontal. In formal seed supply, activities follow each other. This system is rightfully compared with a chain. The main links are plant breeding, seed multiplication and seed distribution. Since a chain is as strong as its weakest link, these links have to be developed in harmony (Coordination) with each other. There is no point in producing seed without a developed distribution system; an efficient seed production and marketing system cannot survive without the supply of breeder's seed and new varieties.

An important distinction can be made within formal seed systems. In many developing countries, it is the existing breeding infrastructure that is looking for ways to get its results to farmers; the chain is driven by the research push.

Local seed supply consists of basically the same components: selection, production and diffusion, but contrary to the vertically organized formal systems, organized in a horizontal manner. Seed production is the focal point here, because seed is the basis for crop production. Selection and diffusion are not necessarily given the same emphasis in every seed production cycle. The horizontal pattern of local seed supply systems seems to imply that they are most suitable. The main factors that have activated a renewed interest in local seed systems are the following:

* The level of economic sustainability of the formal system, which becomes apparent in many countries during the transition from development oriented to market oriented seed supply in a privatization process, leading to a narrowing of the product mix with respect to crops.
* The effects of the choice of seed supply system with regard to the social differentiation of the farmers served, and on differences in influence in plant production within local groups (gender);
* The ability of different seed supply systems to respond to the existing agro diversity, and the effects of the system on in situ conservation of genetic diversity.

**9.4. Seed industry development in Ethiopia**

Seed systems in Ethiopia can be divided into two broad types: the formal system and the informal system (sometimes called local or farmers seed system). Both systems are operating simultaneously in the country and difficult to demarcate between the two. However, the formal system is the original source of improved seeds for the informal system. There is also a system referred to as integrated seed system. Other forms of seed systems operating in both systems also exist such as Community-Based Seed System (CBSS). Though not well developed, few commercial seed systems, as part of the formal system, are also operating in the country.

**Formal Seed System**

The formal seed system is called formal because it is mainly government supported system and several public institutions are also involved on it. The major actors of the formal system are: National Agricultural Research Systems (NARS). Ministry of Agriculture (MoA), Ethiopian Seed Enterprise (ESE) and private seed companies specializing on specific crops. Recently, regional seed enterprises (RSE) were also established as public seed enterprises (such as Oromiya Seed Enterprise (OSE), Amhara Seed Enterprise (ASE), and Southern Nations nationalities and Peoples Region Seed Enterprise (SRSE) and entered into the formal system. NARS (EIAR(Ethiopian institute of agriculture research & RARIs (regional agriculture research institutes ) is responsible for variety development and supply of initial seed, and ESE and RSEs are playing key roles in mass production of improved seeds. MoA is also involved in variety release, multiplication, certification, and distribution of seeds in the country. Private seed growers and other farmer institutions such as unions and cooperatives are also playing key roles in multiplication and distribution of different classes of seeds.

The Ethiopian government has enabling policy framework for agricultural research and technology generation and is fully supporting the research system by allocating appropriate resources. Therefore, the country's agricultural research system (NARS) has developed and released more than 664 varieties of 50 different crop types. ESE has only been able to produce 111 different seeds of just 26 different crop varieties in 2009 cropping season. Seed multiplication by ESE focused mainly on two cereal crops (wheat and maize) and annual supply of certified seed by the enterprise doesn’t exceed 20,000 tons Wheat and hybrid maize constitute about 85% of the total output of the enterprise.

**Informal Seed System**

The informal seed system, also known as local system or sometimes as "farmers" system, is called informal because it operates under non-law regulated and characterized by farmer- to-farmer seed exchange. Five key features distinguish the informal from the formal system. These are, the informal system is traditional, semi-structured, operate at the individual community level, uses a wide range of exchange mechanisms, and usually deal with small quantities of seeds often demanded by farmers.

In the context of some countries like Ethiopia, the informal system is extremely important for seed security. The bulk of seed supply is provided through the informal system, implying its importance in national seed security. About 60% of seed used by Ethiopian smallholder farmers is saved on-farm and exchanged among farmers, and the remaining 20-30% is borrowed or purchased locally. The informal seed system (either self-saved seed or farmer-to-farmer seed exchange) accounts for 90% of the seed used by smallholder farmers, while the share of improved seed is less than 10%. The majority of Ethiopian farmers show a tendency of depending on the informal seed system due to the following key reasons;

* It is relatively cheaper and readily available in the farmer’s villages just at the time of seed is needed.
* It allows use of seeds after testing on primary adopter farmers.
* It is more reliable and its sustainability is more guaranteed than the formal system.

Table 1: Comparison of area coverage (ha) by the informal and formal seed system during 2005/06 to 2009/10



**Integrated Seed System**

The line between the formal and informal seed sectors can become somewhat blurred, as seeds of improved varieties can be saved by farmers and eventually considered as “local variety” or “local seed” after some years of usage. In addition, in Ethiopia there have been attempts made by the government and NGOs to promote quality seed production and distribution through market channels for landrace varieties, although until now the volume they represent is quite small. Thus, the formal and local seed systems are not always as distinct or separated as the two labels may imply something to integrate both systems.

**Current Situation in Ethiopian Seed Systems and their challenges**

Ethiopian seed system has been confronted with several challenges. During intervention activities made so far, the following were identified as major challenges of the general seed system of the country:

* Lack of proper linkage between different actors involved in seed systems;
* Inadequate supply of good quality seed at affordable prices;
* Focus on few crops (maize & wheat) in the formal system and other beneficial crops (such as pulses & oilseeds) remain orphans;
* Low level of private sector involvement in the formal system;
* Inefficient seed promotion, distribution and marketing mechanisms;
* Weak variety release and seed quality assurance system.

**Seed Demand *vs.* Supply in Ethiopia**

Since the establishment of Ethiopian Seed Enterprise as the first public and formal seed sector, the enterprise has remained the sole producer and supplier of improved seeds for over three decades. The enterprise is also playing the leading role for the advent of organized seed production and supply system in the country. Despite the better capacity ESE has, seed supply remained far behind the demand in those years. The huge gap between the demand and supply has existed in the history of the enterprise. The overall annual average seed requirement for cereals, pulses and oil crops is estimated to be over 400,000 tons. However; the average yearly supply of improved seed doesn’t exceed 20,000 tons since the establishment of ESE.

Despite the aforementioned several efforts undertaken by the government, there is often shortage of source seed, which limits commercial seed production in the country, mainly due to mismatches between seed demand and supply the reason is that:

* There is limited capacity to supply as much source seed as demanded and multiplication of initial seed, which subsequently delivered to mass producers,
* The seed multiplication process is not supported by irrigation and almost totally depends on main season rainfall,
* The other main reason is that demands of farmers often become volatile, indicating problems related with demand assessment and forecast during planning process, suggesting demand re-vision based on the dynamic condition of farmers’ situation has paramount importance.
* Moreover, seed production supply system in the country has focused only on hybrid maize and wheat varieties that limited farmers’ option to other beneficial crops. This makes farmers merely depend on farm-saved varieties which are genetically low productive.

Table 2. Demand vs. supply of certified seeds of hybrid and non-hybrid (in qt) over four years



**Seeds Supply by ESE**

Over the past decades, annual seed sell of ESE was between 7,000 to 22,000 metric tons. Most recently, the enterprise has been taking shift in strategy and as a result of crush seed production programs undertaken in 2009/10 cropping season, ESE alone produced about 54,326 tons of certified seeds, of which 52,430 tons (96.51%) is for cereals. This shows that there is a 61% increase in supply as compared to what was supplied in the preceding year (2008/09 cropping season). As indicated in the table, from cereals, about 78% of the produce was the share of wheat seed.

Table 2. Annual certified seed supply by ESE over the last five years (in tons)



**Seed Supply by the Research System (NARS)**

Once a new variety is developed and released from the national agricultural research system (NARS), be it at the federal or regional level, it is mandatory that the variety should be put into the seed production system. This requires a sequence of seed multiplication over several seasons as several classes of seed; as nucleus, breeder, pre-basic, and basic in order to get adequate amount for commercial seed production (certified seed). Since the first three seed classes are mainly produced in the research stations, seed supply by the national agricultural research system (NARS) is focusing mainly on these seed classes which often provided to seed producers to further multiplication as basic seed followed by certified seed. There has been chronic shortage of initial seeds and the research system couldn’t satisfy the demand of commercial seed producers. On the other hand, since the seed system of the country is not well developed, the little amount of seed produced hasn’t been channeled into the appropriate seed system.

Table 6: seeds of different class of produced by EIAR during 2009/10 copping system



Table 7. Performance of breeder pre-basic and basic seed production by EIAR and ESE during 2009/10 production year



In countries like Ethiopia where the formal seed supply is inefficient, the informal system is extremely important for seed security of the nation. The majority of Ethiopian smallholder farmers are largely dependent on this system mainly through farm-saved seed exchange. The system is providing cheaper and readily available in the farmers' village at the right time of seed is needed. As a result, the majority of Ethiopian farmers show a tendency of depending on the informal system. The informal seed system is more reliable and sustainable, and thus need to be strengthened with special emphasis of formalizing the system through integration with the law-regulated formal system. For one reason or another, the private seed sector is still undeveloped in the country. Special attention and support should be offered by the government particularly in making the working environment more encouraging to the private sector. Other farmer organizations involving in seed sector such as unions and cooperatives are also playing key roles in multiplication and distribution of different classes of seeds and other farm inputs. Such organizations, however, couldn’t get capacity building supports so far from the government. Hence, necessary support, particularly with respect to training and important facilities should be provided to these organizations.

The current developments and initiatives in the national seed system have revealed the following key issues that need special attention:

* Effective seed demand assessment mechanisms and genuine involvement of farmers/users during planning phase is crucially important;
* As seed is an expensive product, every seeds produced must be channeled into the seed system. Thus, appropriate systems which can strictly control seed outlets should be in place;
* Demand-driven seed multiplication strategy and supply with value addition in the seed chain (with respect to quality, time and place of supply and fair pricing) should be looked into two-to-three times seed production per year is needed to fill the huge gap between seed demand and supply. Thus, development of irrigation capacity particularly in the NARS seed system should be given the utmost priority;
* Provide opportunities for consolidation of investments on capacity building, basic facilities, infrastructure and training activities on variety maintenance and initial (breeder) seed production at national and regional levels;
* Establish clear and simple institutional and functional linkages between research and seed producing institutions;
* Formulation and implementation of clear seed policies in the country and establishment of executing institutions is highly important!
* capacitate experts and extension agents that can strengthen the entire integrated seed system; and as the involvement of the private seed sector is largely motivated by profit making, seed policies and ethics of seed production and marketing should be maintained so that seed quality shouldn’t’ t be compromised.