Debre Markos University

College of Agriculture & Natural Resources

Department of Horticulture

Horticultural Seed Science and Technology (HORT2084)

Teaching Manual

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Chapter One

1. Introduction

1.1 Seed: Definition and Concept

In broad sense, seed is any plant part which is utilized for commercial multiplication of a crop. It is the various propagules which are obtained either through sexual/ true or botanical seed or asexual (tubers, rhizomes). It is a structure developed by flowering plants after fertilization. Seed is the basic input for agricultural /crop production. True seed is a reproductive unit that develops from ovules and contains an embryo and food reserved which are located either in embryo or in some external storage tissues. In seed technological term the part of the plant used for sowing purpose to raise the crop is considered as seed or it is used to describe any plant part that is capable of producing new plants.

Biologically: a matured ovule consisting of an embryonic plant together with a stored food surrounded by a seed coat which is viable and has the capacity to germinate

Agriculturally (seed technology) production point of view: any planting material for any crop production purpose e.g. tomato seed, potato seed, sweet potato cuttings, cassava cuttings etc.

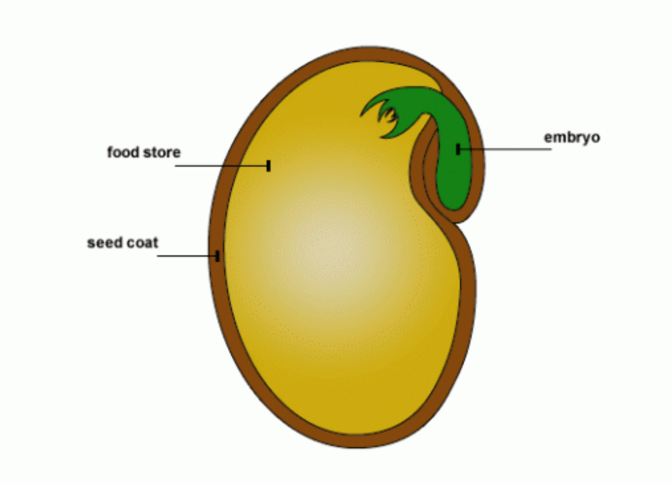
The seed of a released and popular variety produced by scientific method is known as **improved seed or quality seed**. Improved seed plays an important role in maximizing the production and productivity of crops. Improved seed results in better germination, vigorous seedling growth, higher crop stand, better quality of produce and ultimately in higher yield. For successful crop production high quality seed of improved variety is essential.

In any agricultural research, crop production would be little value unless farmers gets seeds which are genetically pure (true to type) which posses other desirable qualities like high germination capacity (percentage) and vigor , high purity and good health etc. It is the basic input and forms only a small part of the total cultivation expenses. Without good seed the investment on fertilizer, water, pesticides and other inputs will not pay the required dividends. The pace of progress of food production depends up on the speed with which we are able to multiply and distribute good quality seeds of high yielding varieties. It is the first link in crop production which resolves the successes of all other factors used for crop production.

1.2 Seed Structure

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

1. **Embryo:** is developed from a zygote. The embryo is surrounded by the endosperm, nutritive tissue. Structural feature of the embryo are *cotyledons, epicotyle, hypocotyle, plumel and radicle*. Embryo is a rudimentary plant present in axis form with one tip known as plumle, responsible to form shoot portion and the other tip known as radicle, forms the root system. The portion of the embryonic extended above the cotyledon is known as the epicotyle and below the cotyledon the hypocotyle (Fig. 1).



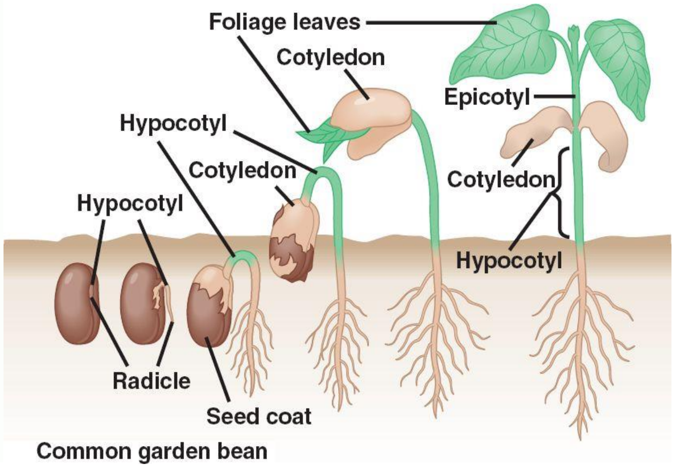


Figure 1. Major seed parts and structure of germinating seed

Cotyledons are extensions of the embryo; one is present in seeds of monocots and two on seeds of dicots. Epicotyle is the base of the plumle and will develop to the upper part of the plant. Hypocotyle is the base of the radical and will develop to the lower part of the stem, is transition between the root and the stem.

2. **Endosperm:** formed by the fusion of two polar nuclei with the second spermatic nuclei. It is used as a food by the embryo and seedling during development of the seed and germination. It is rich in oil, protein and starch. On the basis of presence or absence of endosperm seeds are categorized in to two.
    - Albuminous (endospermic seeds): endosperm present.
    - Exalbuminous (nonendospermic seeds): endosperm absent.
3. S**eed coat:** is outer covering of the seed developed from the integuments. Seed coat is a protective coat made up of two layers, testa (outer thick layer) and tegument (inner thin membrane) present as an envelope to protect the embryo and endosperm from desiccation, mechanical injury, effect of environmental fluctuations and damage due to insects and microorganisms.

1.3 Seed Size

Seeds have diverse sizes that range from the smallest *dust-like seeds* of the orchid to the largest *coco demer* seeds. The dust-like seeds of orchid have about a million per gram and a single *coco demer* seed weighs about 20kg. The smallest seeds are mostly immature embryos with little or no energy reserves. These plants with smaller seed sizes set higher number of seeds from single flower where as those with larger seeds set relatively small number per flower. Orchid and some other plants depend on Mycorrhizal fungus for food preparation during germination.

Figure 2. Seeds of the coco de and small Dandelion seeds

1.4 Types of Seed

Seeds can be classified based on many criteria but their classification based on their viability is the most common way of classifying them. There two major types of seeds:

- ***Recalcitrant seeds:*** these are also called *unorthodox seeds* and defined as those seeds which do not survive on drying and freezing during ex-situ conservation. They do not tolerate extreme drying or temperature of less than 10ºC and hence cannot be stored for a long period of times. If they do, they lose their viability. Plants with such types of seeds include Avocado, Mango, cocao and some other horticultural trees and medicinal plants. Most of the climax species produce such types of seeds.
- ***Orthodox seeds:*** unlike the recalcitrant seeds, those survive drying and/or freezing during ex-situ conservation. The ability of these seeds to withstand drying and freezing differs from plant to plant. Some can be categorized as intermediate orthodox and the other are fully orthodox.

1.5 Concept of Seed Technology

Agricultural productivity especially the productivity of crops completely relies on the quality and type of seed. High quality seed enhances crop productivity. The genetic behavior in any crop species/genus in a species is stored in seed. Therefore, the concept of seed technology as special discipline is nowadays considered as the most important component in crop production practices.

Seed technology is a discipline studying ways and practices of seed production, maintenance, quality control and preservation. It encompasses methods of improving both genetic and physical characteristics of seed through variety development, evaluation, release and large scale production as well as large scale seed production, processing, certification, storage and distribution. It is multi-disciplinary in nature incorporating many more agricultural disciplines. It has strong relationships with the following:

- **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 control during production and storage
- **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
- **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
- **Agricultural extension**: involved in popularizing the use of high quality seeds of high yielding varieties among the farming community.

1.6 Role of Seed in Agriculture

Seeds of agricultural crops have been and will continue to be the major source of food worldwide. Seed is a primary input in crop production, whether agriculture is practiced at commercial or subsistence levels, by large or small-scale producers, or in favorable or less favorable environments. Seed plays the following major roles in agriculture.

1. **Carrier of new technologies**: the introduction of quality seed of new varieties combined with other inputs significantly increases yield level.
2. **Basic tool for secured food supply**: The potential benefits from the spread and use of improved seed are enormous. At the farm level, this means enhanced productivity, reduced risk and increased net income through higher yield, more efficient use of available resources, faster maturation, and better resistance to pests, and higher nutrient content in the harvested crop. This greater flexibility, together with enhanced yield and nutritional value, can contribute to increased food security.
3. **The principal means to secure crop yields in less favorable production areas**: The supply of good quality seeds of improved varieties suitable to these areas is one of the immediate contributions that seeds can make to secure higher crop yields.
4. **A medium for rapid rehabilitation of agriculture in times of natural disaster**: It is a means of survival and multiplication under adverse conditions, which can be used to rapidly rehabilitate agriculture in times of natural disaster such as flood, drought, or due to insects and plant diseases.

1.7 Goals of Seed Technology

The followings are the major goals of seed technology

- *Rapid multiplication:* increases in agricultural production through quickest possible spread of new varieties developed by the plant breeders
- *Timely supply:* the improved seed of new varieties must be made available with in time to increase agricultural production
- *Assured high quality seed:* to obtain the expected dividends from the use of good seed for planting purpose.

- *Reasonable price:* the cost of high quality seed should be used within reach of the average farmers.
- *The development of seed program:* is one of the most important steps in agricultural development.

1.8 Scope of Vegetable Seed Production in Ethiopia

There are many strong justifications for the expansion of vegetable seed production in Ethiopia.

1. Increasing demand of vegetable seed

The production of vegetables is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries, generates employment for its labor intensive. The success of production depends on the adoption of improved technologies such as cultivars that have acceptable standard and high value in the local use and export markets.

2. Environmental suitability for vegetable seed production

Ethiopia's agro-Climatic conditions make it suitable for the production of a broad range of fruits, vegetables as well as cut flowers. The range of altitude, temperature and soil variability of the country has created an enormous ecological diversity and a huge wealth of biological resources. The research and production experiences indicated seed production potential of diverse vegetables crops ranging temperate to tropical types so one can produce all vegetable crop cultivars that have good acceptability in the market.

3. Government Policies

The Government policy and strategy are aimed at broadening the agricultural production by improving the support to research, extension, infrastructure, irrigation and above all the private sector engaged in the production and export of agricultural products (especially in floriculture, horticulture, pulses and oil seeds).

Chapter Two

2. Development of Seed Program

2.1 Introduction

Seed program is a scheme of activities planned and implemented to secure systematically rapid and timely supply of good quality seeds in the required quantities.

A comprehensive seed program has several essential components which are strongly interrelated. The most important of these are "breeding, evaluation, and seed release; multiplication; processing and storage; seed quality control; and marketing and distribution. Each stage must be implemented at the proper time and in the correct sequence. If one component is not operative, the entire seed program will not work properly.

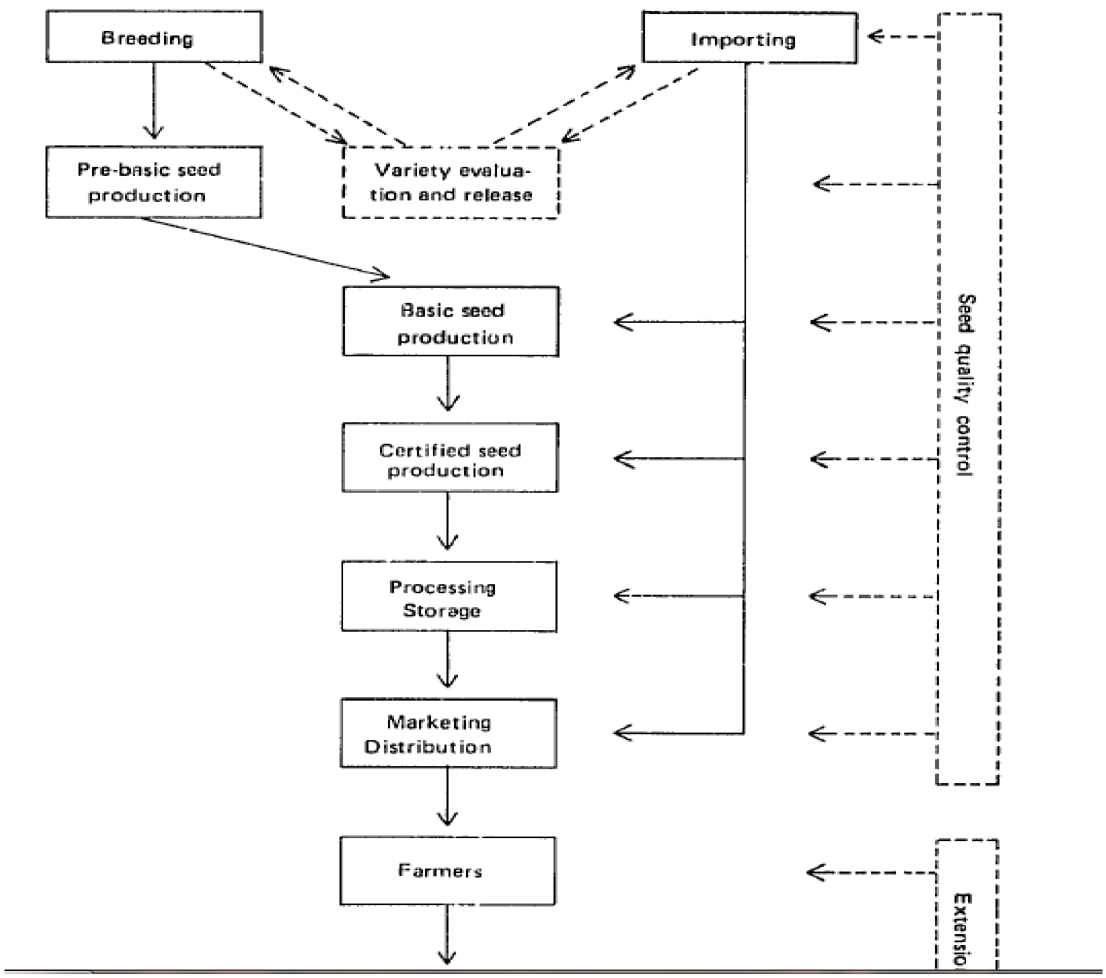


Figure 3. Components of seed program

2.2 Bases for a seed program

There are three bases for a seed program (high level support, productive plant breeding program and coordinated efforts).

1. **High level support:** The desire and determination at the decision making level of the government, to improve agriculture and supply of essential inputs including seeds is the first requisite. Administrative support and an understanding and appreciation of the nature and the potential contribution of the seed program are needed at all levels including those responsible for planning and implementation of programs.

2. **Productive plant breeding program:** A sound seed program must be supported by strong breeding activities. The production of quality seed of traditional varieties seldom generates sufficient benefits to the farmer compensate to for the increased cost of the seed. The breeding program for a new variety produces small quantities of what is called breeder seed. This seed is the parent material for further multiplication, and the source of all certified seed.

3. **Coordinated effort:** a coordinated effort to create producer demand, prepare a sound plan for seed program and establish a cadre of trained specialists is necessary for the success of a seed program.

2.3 Types of seed programs

There are three types of seed programs:

1. **Official Seed Program:** the government holds the full responsibility of developing the program and making good quality seed available to farmers. Probably all seed programs in the world have started with government participation. Disadvantages of official seed program are:

    - The concern for return from investment is very low, or even for covering the cost of production
    - Often subject to political pressures and usually too frequent personnel changes hampers the progress
    - Not very efficient

2. **Semi-official Seed Program:** a semi-official seed program consists of establishing a national agency to produce, process, and distribute seeds. This program is more remote form of the government participation. Such an agency may be established at the initiation of a program or at a subsequent phase of less direct government participation. This program operates as autonomous units and is usually more commercial in nature and management than governmental units, and is more efficient in operation.

3. **Private seed program:** The private enterprises handle the production and distribution of seeds. In developing countries the best approach appears to involve various government, semi-government and private agencies in developing the seed programs by demarcating their broad responsibilities to minimize much duplication of effort and to ensure that the program develops in a coordinated manner.

2.4 Steps involved in the development of seed program

The planning, organization and operation of a seed program is highly technical and time-consuming job. Once a high level decision has been made to begin a seed program, the plan should be prepared carefully. In preparing plan pertinent data should be carefully examined and the various requirements identified based on scientific and technological principles. The main steps in the development of a seed program are:

Step I: Collection of pertinent data

The first step in developing seed program is to collect the correct statistics or status regarding the following factors:

- Availability of superior varieties: the list of available varieties, their area of adaptation and yield, information regarding promising varieties, other advantages should be compiled. In addition, farmers' preference for particular varieties should be considered.
- Availability of other inputs: Statistics on areas under assured irrigation, availability of inputs, etc. helps in fixing realistic targets of production.
- Targets for area under high yielding varieties fixed by national governments
- Total area under various crops included in the program, seed rate per hectare, and desired renewal period to calculate total potential demand.
- Role played by extension agencies in popularizing seeds
- Collection of climatic data: detailed climatic data is necessary for the preparation of a calendar of operations of seed production and processing, and working out requirements of seed drying, processing, storage and movement of seeds. In horticultural crops which need vernalization temperature for flower initiation, development and subsequent seed set, temperature data should be recorded.
- Farm size, methods of cultivation and harvesting
- Financial resource of seed growers
- Multiplication scheme

Step II: Assignment of Broad Role to various agencies responsible in the seed industry (stakeholder analysis)

The formal seed sector in Ethiopia comprises both public and private organizations, including Ethiopian Biodiversity Institute (EBI), Ethiopian Institute of Agricultural Research (EIAR), Regional Agricultural Research Institutes (RARIs), Universities, Ethiopian Seed Enterprise (ESE), Pioneer Hybrid Seed Ethiopia (PHSE), several small-to-medium scale private seed farms and the farmers. Other relevant stakeholders are the Ministry of Agriculture and Natural Resources, Bureaus of Agriculture, Cooperative, Unions and NGOs.

1. Ministry of Agriculture and Natural Resources

Ministry of Agriculture and Natural Resources is an umbrella organization which coordinates and leads the various activities of the seed industry. Its task includes the national seed policy, variety registration and release, seed import/export, seed certification, quarantine and extension.

It has also a role in seed industry development including planning at the national level, ensuring uniform standards, standardizing procedures of seed certification, etc. It should hasten and facilitate the adoption of new technologies of seeds.

2. The National Seed Industry Agency (NSIA)

Roles/responsibilities:
It encourages seed industry to develop and operates efficiently; to ensure that the seed producers and the farming community to create an enabling environment for capacity building in research, development and training in the field of genetic resource conservation, crop improvement and seed technology.

3. Ethiopian Biodiversity Institute (EBI)

The responsibilities of EBI are to collect, characterize, conserve, document and utilize the germplasm resources of edible, economically and medicinally important plants. It provides and makes available genetic materials for breeders to develop improved varieties for cultivation.

4. Research Institutes

The Ethiopian Institute of Agricultural Research (EIAR) by large and Regional Agricultural Research Institutes (RARIs) and Agricultural Universities to a certain extent are the plant breeding research institutes in Ethiopia. Variety development has long been the sole responsibility of the EIAR. Since research decentralization, RARIs have increasingly been commissioned to develop varieties suitable for their regions. The responsibilities of Research Institutes in Ethiopia include guiding, coordinating and promoting agricultural research. They should pay attention to the introduction and release of new varieties, strengthen research in plant breeding and allied subjects, produce, maintain and multiply breeder's and foundation/basic seeds and arrange and provide training on seed technology. The EIAR and the RARIs produce breeder seed and parental lines. The EIAR and the ESE are responsible for pre-basic and basic seed supply.

5. Ethiopian Seed Enterprise (ESE)

Roles/responsibilities
The ESE is the major seed producer in the formal seed system, and owns seed farms where it produces largely pre-basic and basic seeds of different crop varieties. It organize large scale production and marketing of improved seeds, import reliable high yielding varieties, organize seed cleaning and processing facilities and act as a promoter of seed enterprises

6. Ethiopian Pioneer Hybrid Incorporated

Pioneer Hybrid Incorporated entered into a joint venture with ESE to produce basic seed of improved varieties mainly hybrids.

Step III. Planning and organization of the seed program

Once the goals and scope of the program have been established, the seed program can be planned and organized based on the following guidelines:

- Fix the targets of production on the basis pertinent data and growers demand
- Calculate the production requirements for each seed class in terms of land required
- Workout the personnel, equipment and facilities requirement and the associated costs (technical, administration)
- Survey on seed marketing and pricing structure
- Prepare a detailed calendar of operations

Chapter Three

3. General Principles of Seed Production

3.1 Basic principles of seed production

The seeds of different crops have different behavior both in their genetic makeup and their response to the environment. Those seeds from cross pollinated plants have higher potential for genetic mixing up with other varieties than self-pollinated crops. Production of genetically pure seed requires high technical skill and specialization. Seed production must be carried out under standard and well-organized conditions. Moreover, producer should be familiar with genetic and agronomic principles of seed production. Therefore, there is always a need to have guiding principles of producing different types of horticultural seeds from different crops.

Seed production program requires the application of good farming practices along with careful management of crop. In seed production two types of principles of seed production should be followed: the genetic principles and agronomic principles.

3.2 Genetic principles

For quality seed production, strict attention must be given to the maintenance of genetic purity and other quality of seeds. Genetic purity refers to absence of seeds of other variety of the same crop as well as other crops. The variety should be pure with all of its own characteristics. All seeds used for sowing must have similar genetic constitution for uniform performance and quality produce. Maintaining the genetic purity of the seed is of utmost importance and will enable growers to exploit the full benefits of introducing improved varieties of seeds. Permanent reduction either in the genetic or agronomic value of a released variety is known as **varietal deterioration**. The genetic purity of a variety/trueness to its type deteriorates because of several factors during the production cycle. The following factors are responsible for deterioration of varieties.

1. **Developmental Variations**: when seed crops are grown under environments with differing soil, fertility, climate, photoperiods, or at different elevations for several consecutive generations, developmental variations may set in as differential growth responses and can favor some specific genotypes of a variety. When any variety is exposed to an unsuitable environment the beneficial trait may not be well expressed due to environmental suppression. It cannot give the expected yield and quality seed. It is, therefore, preferred to grow the varieties of crops in the areas of their natural adaptation to minimize developmental shifts.
2. **Mechanical Mixtures**: This refers to mixing up of seeds of different varieties usually of a crop species. The most important reason for varietal deterioration, often take place at the time of sowing if more than one variety is sown with the same seed drill, through volunteer plants of the same crop in the field, or through different verities grown in adjacent fields. Two varieties grown next to each other in a field are usually mixed during harvesting and threshing operations.
3. **Mutations**: Can also cause deterioration of a variety.

4. **Natural crossing**: an important source of varietal deterioration in sexually propagating crops. The extent of contamination depends up on the magnitude of natural cross fertilization. The deterioration sets in due to natural crossing with undesirable types, diseased plants, or off types. In self-fertilized crops, natural crossing is not a serious source of contamination unless the variety is male sterile and is grown in close proximity with other varieties. The natural crossing, however, can be a major source of deterioration in cross fertilized crops. The main factors deciding the extent of contamination due to natural crossing are the pollination system of the species, isolation distance, varietal mass, and pollinating agent.
5. **Minor genetic variations**: can occur even in varieties appearing phenotypically uniform and homogeneous when released. Due care during the maintenance of breeder seed of cross fertilized varieties of crops is necessary to overcome these minor genetic variations.
6. **Selective influence of diseases**: sometimes an improved variety deteriorates since it is infested by disease to which it was considered resistant at the time of its release. This can result either because of (i) absence of such disease in the area where the variety was tested or (ii) formation of new races of a disease. Seed production under strict disease free conditions is, therefore, essential.
7. **Technique of the plant breeder**: Premature release of varieties, still segregating for resistance and susceptibility to disease or other factors, can cause significant deterioration of varieties.

Maintaining the genetic purity of seeds

a. **Controlling seed source:**
   - It is the use of approved seed during seed multiplication
   - It is critical to utilize a seed of an appropriate class and from an approved source for raising the seed crop.
   - Four classes of seeds, namely, breeder's, foundation, registered and certified seeds

b. **Inspection and approval of fields prior to planting:**
   - It is performed to check for the presence of volunteer crops, weeds and disease history
   - To test adaptability, nutritional status, soil born disease and pest

c. **Crop Rotation:**
   - Satisfactory intervals between related or similar crops is required to minimize the risk of plant material or dormant seeds remaining from the previous crops, which are likely to cross-pollinate or make admixture with the planned seed crop.
   - In addition crop rotation helps to enhance plant nutrition, maintenance of soil physical condition and minimizing the risk of soil-borne pests and diseases.

d. **Isolation:**
   - Minimize the possibility of cross-pollination between different cross-compatible plots or fields
   - It avoids admixture during harvesting and the transmission of pests and pathogens from alternative host crops.
   - Horticulture seed crops can be isolated by time and by distance

<u>Isolation by time:</u>

☞ Cross pollination may also be checked by adopting different time of sowing for different varieties so that their blooming periods will not coincide with each other.

I<u>solation by distance:</u>

- ☞ Seed plot is grown at a particular distance from the source of genetic contamination so that the foreign pollens are unable to reach in viable state.
- ☞ Isolation distance primarily depends on the nature of pollination of the crop. E.g.
    - o Insect cross-pollinated vegetable crops like onion, radish, cabbage, cauliflower and cucurbits require isolation distance of 800-1000 meter
    - o While wind pollinated vegetables like spinach, beet requires isolation distance of about 2000 meters.

<u>Barrier isolation</u>:

- ☞ Isolation can be maintained by providing physical barrier of optimum height around the seed production plot. It reduces the movement of wind-blown pollen by controlling the velocity of wind. Physical barrier of polyeten sheet of 2 m height is recommended to maintain genetic purity.

e. Rouging off seed crops:

- ✓ The existence of off-type plants in the seed crop is a potential source of genetic contamination.
- ✓ Not only the off-types but the diseased and abnormal plants are also to be removed.
- ✓ Rouging may be done at the following stages as soon as the off-types are recognizable (vegetative, flowering, and maturity stage).

f. Periodic testing of varieties for genetic purity

- ✓ Varieties being grown for seed production should periodically be tested for genetic purity by grow-out tests to make sure that they are being maintained in their true form.
- ✓ It is important to cultivate each crops in their suitable environmental conditions

g. Seed certification:

- ✓ Seed certification implies that the crop and seed lot have been duly inspected and that they meet requirement of good quality pedigree seeds.

3.3 Agronomic Principles

Besides to genetic principles, the application of the following agronomic principles is essential to preserve good quality and abundant seed yields.

Selection of Suitable Agro-climatic Region

A crop variety to be grown for seed production in an area must be adapted to the photoperiod and temperature conditions prevailing in that area. Regions of moderate rainfall and humidity are much more suited to seed production than regions of high rainfall and humidity. Most crops require a dry sunny period and moderate temperatures for flowering and pollination. Excessive dewand rain cause hindrance in normal pollination resulting in poor seed set. Similarly too high temperature causes desiccation of pollen resulting in poor seed set. If hot dry weather conditions prevail during flowering, many crops such as vegetables, legumes and fruit trees fail to set seed effectively and produce many seedless fruits. The crops invariably require cool conditions with low atmospheric humidity to flower and pollinate normally.

Excessive rainfall also leads to a higher incidence of diseases and makes seed harvesting extremely difficult. It may also result in delayed maturity and pre-germination of seed in many standing crops. Strong winds and heavy rainfall at or near harvest time may cause heavy seed losses particularly in crops which have a tendency to shatter their seed readily.

It is therefore clearly evident that ample sunshine, relatively mode rate rainfall and the absence of strong winds have essential advantages for productive and high quality seed production and must be kept in view in the selection of areas for seed production.

Selection of Seed Plot

The plot selected for seed crop must have following characteristics:

- Soil texture and fertility of plot should be according to the requirement of the seed crops.
- 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

Isolation of Seed Crop

The seed crop must be isolated from other nearby fields of the same crop and other contaminating crops as per requirements of certification standards. The isolation of a seed crop is usually done by providing distance between seed fields and contaminating fields.

On a smallscale seed production, the isolation can also be provided by enclosing plants or group of plants in **cage** or enclosing individual flowers or by removing male flower parts and then individual artificial pollination.

Preparation of Land

Good land preparation helps improved germination, good stand establishment and destruction of potential weeds. It also aids in water management and good uniform irrigation.

Selection of Variety

The variety for seed production must be carefully selected. Except in exceptional cases it should satisfy the following criteria's:

- Adapted to agro-climatic conditions of the region.
- High yielder
- Possess other desirable attributes such as disease resistance, earliness, grain quality, etc.

Seed Treatment

The seed may require seed treatment before planting, if they are not already appropriately treated. Depending on the requirement, the following seed treatments may be given:

- Chemical seed treatment
- Bacterial inoculation for legumes
- Seed treatment for breaking dormancy

Time of Planting
The seed crops should invariably be sown at their normal planting time. Depending upon incidences of disease and pests, some adjustments could be made if necessary.

Seed Rate
The optimum seed rates vary with crop, variety, location and method of planting. Seed rates may also differ among varieties depending on seed size and the method and time of sowing. The recommended seed rate should be used when a crop is sown at normal time to achieve the right plant population for adequate competition with weeds and for better yield.

Planting at a higher rate than the recommended rate, is not encouraged because of its negative impact on seed quality, particularly on seed size and weight.

Method of Sowing
The most efficient and ideal method of sowing is by row planting or mechanical drilling, as it allows the deposit of the seeds in desired amount at uniform depth. The sowing of seed crops in rows helps in conducting effective plant protection measures, rouging operations and field inspections.

Table 1. Comparison between seed broadcasting and row planting

Method of planting	**Consequences**
Broadcasting	• Requires more seed • Difficult to adjust seed rate • Uneven planting depth and distribution • Difficult for mechanical weeding and fertilizer application • Produces lower yields
Row planting	• Requires less seed • Simple to adjust seed rate • Proper planting depth, good distribution • Easy for weeding and fertilizer application • Easy for inspection and rouging • Can combine planting and fertilize application • Risk of mechanical mixing (in planters) • Produces higher yields

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

Rouging
It includes removal of volunteer plants, off types, diseased plants, other crop plants, and objectionable weed plants. Adequate and timely rouging is extremely important in seed production. They may differ from normal plant population as a weak or sickly or bolters or dissimilar. They cause quick deterioration in seed stocks by cross pollination, transmission of diseases etc. They should therefore be removed at earliest possible date before flowering. It is wise to remove the whole plant and not just the flower head.

The number of rouging necessary will vary with the crop, cleanness of planting seed and stage of the multiplication of the seed crop.

Supplementary Pollination

Provision of honey bees in hives in close proximity to the seed fields of crops largely cross pollination by insects, ensure good seed set and there by greatly increase seed yields.

Weed Control

Weed control is a basic requirement in producing good quality seed. Weeds may cause contamination of the seed crop in the following ways in addition to reduction in yield:

a) Leads to mixing of weed seeds with crop seeds. In many instances, it is difficult to remove them during the processing of seeds
b) May serve as host to number of diseases

Effective weed control therefore would be necessary to obtain good seed yield and to avoid contamination.

Disease and Insect Control

Poor disease and insect control affects seed quality in the following three ways:

a) There are a number of diseases which are systemic. If these are not checked the seed produced will get infected with spores of such diseases and produce diseased plant in next season.
b) There are certain diseases which are not systemic, leave their spores on seed coats.
c) Seed yield and quality are reduced

The following principles may be applied for an effective management of diseases and pests.

- Plant only treated seed
- Spraying for effective disease and insect control
- Rouging of diseased plants

Nutrition

It is advisable to know and identify the nutritional requirements of seed crops and apply adequate fertilizers. High nitrogen levels may promote vegetative growth, delayed maturity, promote foliar diseases, lodging and reduced yield and seed quality.

Phosphorus is essential for enhancing seed maturity, and potassium for enhancing seed development. Apart from the type of fertilizer, the time and method of application of the fertilizer is very important. Phosphorus and potassium are relatively stable in the soil and can be applied at the time of planting. However, nitrogen fertilizers are volatile, a minimum of two split applications is necessary, i.e., one at planting and the second during crop growth.

Irrigation

Availability of irrigation water is important for a good seed crop. The irrigation regime should be scheduled according to the crop growth stages. The seed crop must receive ample water at two critical stages of crop growth, i.e., during establishment/vegetative growth and early phase of seed development. Moisture stress at these two stages will adversely affect the yield and quality of the seed. Less water during flowering promotes seed setting while ample water after flowering will ensure the development of the greatest possible number of seeds, thus increasing seed yield. On the other hand, irrigation at physiological maturity will delay harvest maturity. In seed production, surface irrigation is preferable because overhead irrigation may affect pollination and encourage foliar and seed-borne diseases.

Number of irrigation varies from crop to crop and also depends on types of soil. In general lighter soil needs more frequent irrigation than heavy soil.

Harvesting, Drying and Storage of Seeds
Harvesting of seed crop must be done at the time that allows both the maximum yield and the best quality seeds. In general, the seeds are harvested when their moisture content is about 15-20%. In order to preserve seed viability and vigour it is necessary to dry seeds to safe moisture content level. The drying of seeds may be done by sunlight, chemical desiccants and by mechanical driers. For short period storage clean and dried seeds should be filled in neat and clean sacks or bags and stored in a clean, cool condition.

3.4 Seed classes

Four classes of seeds are generally recognized by AOSCA (Association of Official Seed Certifying Agencies) in seed certification

I. **Breeder seed:** a seed or vegetative propagating material which is directly controlled by sponsoring breeder of institution & which provides increases of foundation seeds.

II. **Foundation seed:**
- ✓ It is a seed stock so as to maintain specific genetic identity and purity and may be designated or disturbed by agriculture experiment station.
- ✓ Production must be carefully supervised by representatives of the station.
- ✓ Foundation seed is the source of all other certified seed classes, either directly or through registered seed.

III. **Registered seed:** The progeny of foundation and it is handled so as to maintain genetic identity and purity and that has been approved by and certified by certifying agencies.

IV. **Certified seed:** It is the progeny of foundation, registered or certified seed, and has been approved and certified by certifying agencies.

Chapter Four

4. Seed Production in Selected Vegetable Crops

4.1 Introduction

The production of vegetables is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries, generates employment for its labor intensive. Generally Ethiopia has favorable climatic conditions for seed production of various crops ranging from temperate to tropical vegetables. The successful seed production of these crops depends on the supply of good quality seed. Cultivation practices for seed production require more detailed attention and special skills compared to field crops. In Ethiopia, the range of vegetable crops grown from true seed is diverse but the most common crops produced by the small and state farms are tomato, onion, capsicum, cabbage, carrot, beetroot, shallot and melons.

The central and upper rift valley belt which is demonstrated for high yield and quality produces are promising location for various types of tropical vegetables seed production such as melon, tomatoes, capsicum, alliums, beans etc. Biennial vegetables like carrot, beets, head cabbage and Swiss chards perform well in the highlands of Ethiopia that are greater than 2000 m.a.s.l and temperature of 15-25/5-10^{o}c (day and night). Recently seed production potential studies of cool season vegetables have been under taken in the highlands of Ethiopia that correspond to temperate climatic conditions at 2000-3000 m.a.s.l at Bokoji (Arsi highland), Ankober (northern Shoa and Lai Gaint, (Southern Gonder) in 12 months planting dates. As noted these crops require cooler climate for vernalizing the dormant bud and develop flower stalk and then warmer conditions for seed development.

From 1999 to 2007 totals of 65.1, 6.1, 1.9, 0.4 and 1,922.2 kg of onion, tomato, pepper, papaya and potato, respectively, were produced by EIAR. Similarly, during the same period, the Horticultural Development Enterprise (HDE) produced 229,500 and 2,600 kg vegetable and flower seed, respectively. However, a large quantity of vegetable seed is imported annually from abroad. This situation is of great concern to the country **(Fig. 4).**

The seed production potential for the most important and most common vegetables like onion, tomatoes, pepper, carrot beet root, kale and snap bean have been tested in potential growing sites. The result indicated that seed of the economically important vegetables could easily be produced in the country. This indicates that most of the currently imported vegetable seeds could be successfully and easily produced in the country.

A seed research program has been going on for some vegetable crops (onions, tomatoes, capsicums, carrot, beet root, and Cole crops (cabbage and kale), and promising results were obtained (**Table 2**). However, since there is no organization involved in the multiplication and distribution of vegetable seeds, it is advisable to train vegetable producers on the basic principles of seed production at least for their own requirements.

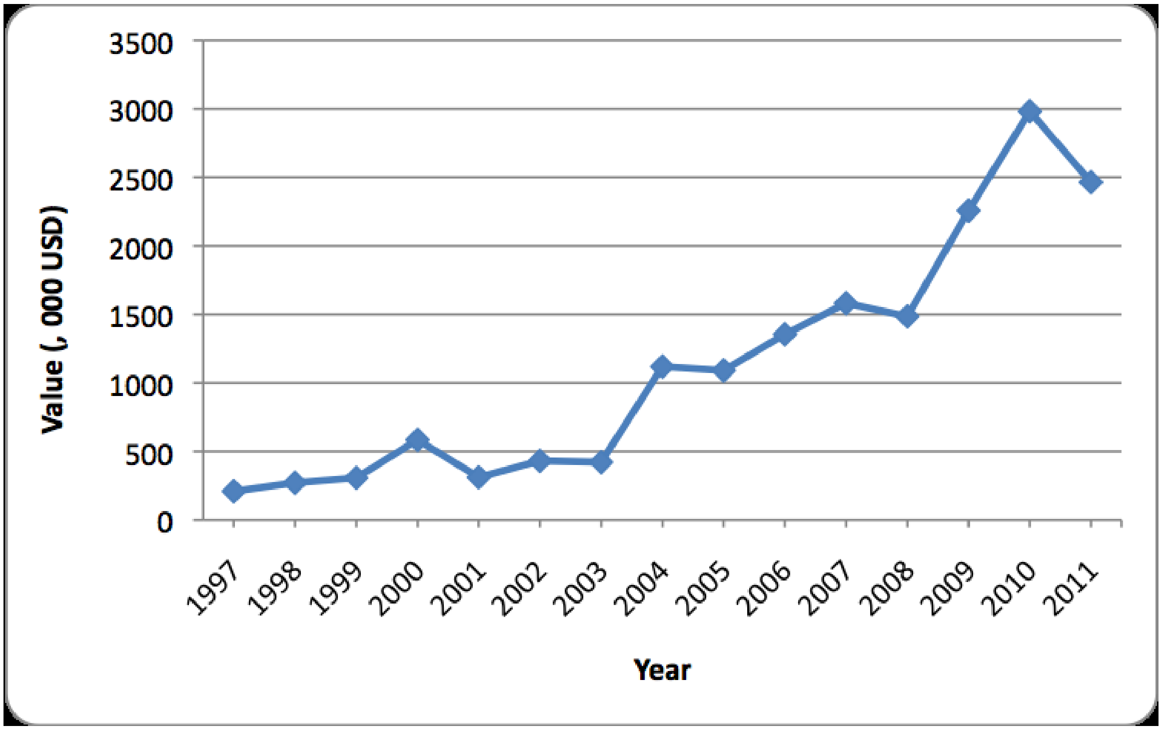


Figure 4.Value of vegetable seed import to Ethiopia in the years from 1997 to 2011. **Source**: Tabor and Yesuf, 2012

Table 2. Potential seed yield of different vegetable crops tested in Ethiopia

No	Vegetable crop	Variety(cultivar)	Potential average seed yield (qt/ha)
1	Onion	Adama red	10-13
		Melkam	11-15
		Red Creole	2-6
2	Tomato	Melka shoal	1-1.2
		Marglobe	1-1.5
3	Hot pepper	Marekofana	2-5
4	Carrot	Chanteny	8-12
5	Beet root	Crimson globe	7-9
6	Cabbage	Copenhagen Market	3-5
7	Kale	Local	6-7

4.2 Seed Production in Selected Vegetable Crops

4.1.1 Tomato *(Lycopersicon esculentum)*

Tomato is a self-pollinated crop but, insects may cause some degree of crossing. It follows the breeding/improvement methods developed for self-pollinated crops. Tomato varieties have been developed for fresh market and processing (canning).

Different types (growth habit, fruit shape, etc.) of tomato varieties are produced in Ethiopia. These include the tall set (indeterminate), erect and bushy types with fairly thin or thick stem, and the short set (determinate) with strong or weak stem. The determinate types produce more flowers within a given length of vine within a short period than the indeterminate ones which produce fruits and highest yield for long time.

Growth Requirements
Tomato seeds should be obtained from breeder's and/or basic seeds from a recognized source (e.g. EIAR, ETFRUIT). The seed is sown at rate of 60 gm/25m^2. The seed is preferably sown on raised nursery beds (15-20 cm height form the ground). Optimum spacing on nursery bed is 4-5 cm between rows. A total of 12 nursery beds (1x5m) are needed to raise enough seedlings to transplant 1 ha. Application of Farm Yard Manure (FYM) during land preparation and recommended rate of DAP fertilizer is very important.

Tomato requires worm, clear, dry conditions, and altitudes ranging between 700 and 2000m. The optimum growing temperature in the central lowlands ranges between 24 and 28°C during the day and 14 and 17°C at night. This is favorable for high quality fruit production and subsequent seed set. High temperature above 40°C during the day and 22°C at night can cause flower drop, poor fruit set and poor quality seed. In addition to temperatures, friable and sandy loam soil with pH of 5.8 to 6.8 is favorable for high fruit yield and better seed set

Pest, disease and weed management (leaf spot, damping-off, cut worms) should be performed with maximum possible care. Watering should be performed by following recommended amount and frequency by taking in to consideration the weather condition, stage of plants and soil condition. Transplanting is performed at 30-35 DAS (days after sowing) at the time seedling reaches 12-15 cm height.

Isolation distance required for basic seed production is 50 m where, as 25 m isolation is required for certified seed or less than 10 m may be used if pollinating insects absent. Spacing in the field is 100 cm x 30 cm (33,330 plants/ha).

Field operations
The field culture of tomatoes for seed production is identical whether they are grown for fresh market or processing. It is grown under irrigation in the dry season. Rain-fed production is not preferred due to heavy disease incidence and poor seed set.

Tomatoes should be grown on the same field ones every 2 to 3 years. Related crops such as potatoes and hot pepper should not be used in the years rotation to avoid diseases build up. Frequent watering, weeding, frequent cultivation, disease control and pest incidence are essential for good seed yield. Staking is important for tall set varieties to facilitate management practices and to produce high quality seed, whereas short set cultivars could be grown without support.

Harvesting & extraction of seed
Depending on cultivars high quality fruits could be harvested from 90 to 120 days after transplanting for about 4 to 5 times for short set and about 6 to 7 times for tall set cultivars.

Good fruits selected from healthy and true to typical plants should be collected for seed extraction. The fruits must be free from diseases, any physical damage and must be typical to the variety in color, size, shape, etc. The fruit should be red ripen as seed extract from unripe green fruits will have low germination percentages and the seed will be not easily separated from the pulp. Rejected fruits should not be used for seed. Since tomato seeds are embodied in a jelly like substances, their extraction requires special care. Different extraction methods can be used depending on availability of facility, technology and amount of seed to be extracted.

a. Manual Seed Extraction:

Procedures;

1. Harvest the fruits in nylon bags
2. Crush the fruits by trampling with feet
3. Put the bags of crushed fruits into big plastic containers and allow fermenting
4. Take out the mass into an open plastic container (e.g. Buckets) then, fill up the container with water and stir the seeds to allow the pieces of flesh and skin sticking on the seeds to float.
5. Incline the container and gently remove the floating flesh and skin, making sure that the seeds remain at the bottom.
6. Repeat the washing several times until clean seeds remain at the bottom.

Figure 5. Manual extraction of tomato seed

b. Mechanical Seed Extraction: Mechanical seed extraction is used by large-scale operations.

Procedures;

1. Put the ripe fruits into the mechanical extractor for crushing
2. Collect the crushed mass (seed + gel-mass), i.e., the juice, pulp + seed) into a suitable container such as buckets
3. Add 0.7% HCl at the rate of 7 ml/kg seed gel mass
4. Stir for about 30-40 min., until the gel is dissolved
5. Pour the acid treated seeds into a clean plastic container e.g. Buckets
6. Fill in the container with tap water and stir gently to allow the pulp and skin to float
7. Incline the container and remove the floating material

8. Collect the seeds that remain at the bottom of the container.

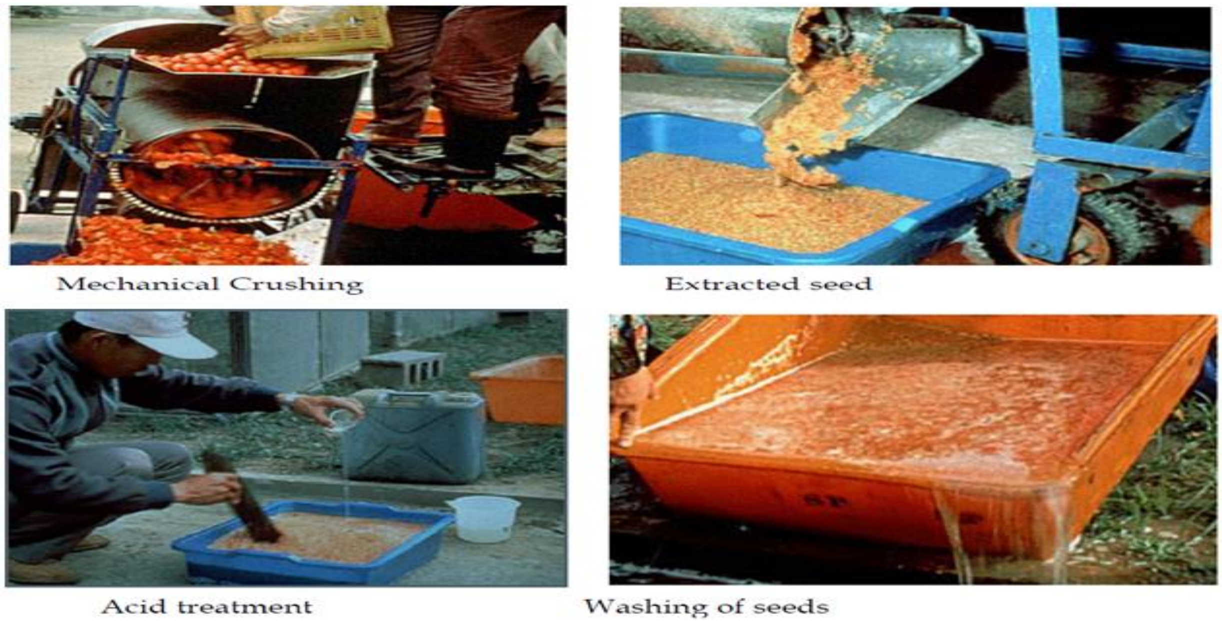


Figure 6. Mechanical extraction of tomato seed

Seed drying

Excess water can be removed by hanging the seeds in the shade for a day. An even quicker way to remove water is to place the seeds in a spin dryer. After the excess water is removed, uniformly spread the partially dried seeds in a flat plastic container or aluminum pan. Loosen any clumps of seeds. Enclose this container with its seeds into a net nylon bag. Place the container into an air drier. Drying continues for three to four days, maintaining a temperature of 28-30°C. Higher temperatures at the time of drying may cause seeds to germinate. Stir the seeds two to three times daily so that seeds dry uniformly. These procedures will get the seeds to the desired 6-8% moisture content.

Seed yield

Temperature**,** rainfall, cultural practices and characteristics of cultivars which include number of fruits per plant and number of seeds per fruit affect seed yield of tomatoes. Small fruited varieties produce about 8 to 10 fruits, while large fruited produce 3 to 4 fruits per cluster. This makes differences in the amount of seed yield. Seed yield can be between 90 to 125 kg per ha. The 1000 seed weigh is about 2.3 to 2.7 g, with 92 to 97 germination percent and a germination rate of about 6 to 8 days.

Seed Storage

Under local conditions, the dried seed can be stored in plastic or cloth bags under cooler conditions or hanged in shade in open air until the new planting season. Under commercial production, tomato seed could be better stored in a sealed condition. The seed can retain full viability for about 3 to 4 years when stored at room temperature, at low moisture content (7 to 9%) and relative humidity up to 70 %. Label each container with name of the variety, year of production, seed class, moisture content, etc.

4.2.2 Onion *(Allium cepa L.)*

Onion (*Allium cepa*) is considered as one of the most important vegetable crops produced on large scale in Ethiopia. The area under onion is increasing from time to time mainly due to its high profitability per unit area and ease of production, and the increases in small scale irrigation areas. The crop is produced both under rain-fed in the meher-season and under irrigation in the off season.

Growth Requirement

Temperature greatly influences the flowering activity of onion. Cool condition with an adequate moisture supply is most suitable for early growth of onion, followed by warm, drier conditions for maturation. Low temperature (9 -17°C) is required for flower stalk development. In the Upper Awash and the Lake region, during September to February with temperatures of 26 to 28°C during the day and 11-16º C night supplemented with low humidity are good conditions for flower stalk emergency and satisfactory seed set for easy bolting varieties. Drier and low humid condition with ample sun shine and the absence of strong wind are suitable for seed maturity, ripening and harvesting. Excessive rainfall and cooler conditions during flowering leads to disease and poor fruit set and ripening and make the harvesting of seed difficult. A fertile loam soil with pH of 6.0 to 7.0 is suitable higher yield.

Pollination and isolation

It is a biennial and cross-pollinated (insects) crop. The intensity varies between 30 to 94% depending on the availability of pollinators. The pollen usually shade before the female part is recessive (protandry). This makes self-pollination impossible without bagging or caging the flowers. The availability of suitable pollinators such as honey bees which feed on nectars and transfer pollen within an umbel and between different plants is very important. Honey bee hives could be placed on the farm to effect seed setting.

In order to get pure seed, varieties should be separated by a distance of at least 600 m - 800 m. If there are many varieties, varieties must be covered with insect proof cages to avoid seed contamination. In a commercial production, it would be advisable to concentrate on one or two varieties.

Method of seed production

There are two methods of seed production; the seed to seed and bulbs to seed methods. But, bulb to seed method is most commonly used method of seed production.

a) Bulb to seed method

The bulb to seed is the most commonly used method in Ethiopia. This method has a number of merits; options of selection of bulbs of good size, uniform, typical color, free from diseases and physical damages. It produces several stalks per bulbs hence gives higher seed yield. Seed yields up to 20 qt/ha can be obtained on farmer's field for the variety Bombay red. The method is also good to maintain the variety identity. However, in this method it takes 10-11 1/2 months to produce seed (4 - 4 1/2 months for bulb production and 6-7 months for seed set and maturity).

In this method, the seed is sown in raised bed at 4-5 cm spacing for raising the seedling. The seedlings of 12-15 cm length are transplanted and this height attained 7-8 weeks after the seed sowing. Thus, 6-8 kg seed ha^{-1} is sown. The seedlings are transplanted in previously developed beds in 15x10 cm spacing. The recommended cultural practices followed to raise healthy bulb crop.

Figure 7. Production of onion seed from bulb.Bulb selection (left), field, drying and packaging (sack and aluminum foil)

The bulb are lifted when the 75% plant show neck fall/top die down. The bulbs are dried /cured under naturally ventilated place then neck is trimmed leaving 2-3 cm attached with bulb. The bulbs are roughed at this stage based upon the color, shape and size. The damaged, twin bulbs and long necked bulbs if any are discarded. The medium size bulbs weighing (50-80 g) bulbs are selected and stored. The bulbs are examined again before replanting in the following season. The bulbs selected for seed production usually referred to as mothers' bulbs.

b) Seed to seed method:
In this method seedlings are transplanted and allowed to over-winter at the same place and allowed to bolt (flowering). This method does not allow to examine the mature bulb characters and field is rouged for off-types. Seed to seed method is not popular, since all the varieties are not suitable for annual seed production due to poor bolting habit and lower seed yield. The seed produced in this method is not suitable for further multiplication.

Field inspection
Field inspection is arranged at mother bulb production and seed production stage.

(a) **Mother bulb production stage**: A minimum of two inspections shall be made as follows;

- The first inspection shall be made after transplanting of seedlings in order to determine isolation, volunteer plants, off type including bolters and others.
- The second inspection shall be made after the bulbs have been lifted to verify the true to typeness.

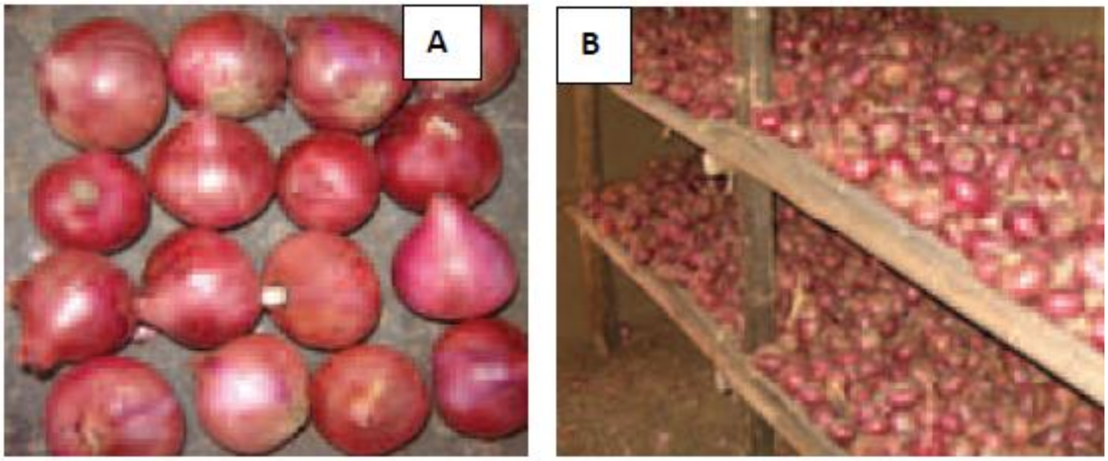


Figure 8. Quality and true –to- type bulbs section (A) and storing under good storage condition

b) **Seed production stage;** A minimum of four inspection shall be made as follows.

- Before flowering for isolation, volunteer plants, off types including bolters.
- The 2nd and 3rd inspection at flowering to check the off type etc.
- Fourth at maturity to verify the true nature of plant and other relevant factors.

Harvesting

All umbels per plant do not mature at one time due to difference in the stalks to flowering; hence harvesting may take 3-4 times. Also, one could stat harvesting when greater than 10 % of black seeds are exposed on an umbel. However, it is better to harvest mature umbels when about 50% black seed is exposed on an umbel; if overstayed the seed heads shatters the seeds readily in the field. Harvesting is done by hands. When heads are cut should be supported in the palm of hand and held between the fingers to avoid seed shattering **(Fig. 9)**

Figure 9. A mature umbel ready for harvest

Drying umbels: The harvested umbels should be dried by spreading the umbels on canvas and putting under shade or in the morning or late afternoon sun for few days.

Seed extraction: The seeds must be properly separated from the umbels. While seed extraction there should not be any damage to seed. Seeds can be threshed by mowing or rubbing of dried umbels and then cleaning the seeds by winnowing followed by pure seed separation by floatation.

- The dry umbels are gently mowed and winnowed to separate the seeds from chaffs
- The winnowed and unclean seed be put in a bucket and soaked with clean water and left for 3-5 minutes in the water
- Then pure seed be separated from light seeds and other trashes based on their weight after 3-5 minutes soaking; heavy seeds sinks and poor quality seeds and chaffs floats

Seed drying: The pure seed settled in a container should be taken immediately and dried under the morning and late afternoon sun or under shade for 3-4 days; should not be dried in the sun during noon the time.

Seed Storage: Onions possess one of the most rapidly deteriorating seeds among major crops. Dried seed should be stored in porous materials such as cloth or paper bags or similar materials in dry and aerated conditions at 7-9 % moisture. Do not store in plastic bags for long time. The seed moisture could significantly affect seed quality. If seed moisture content is high, normally it loses its viability at faster rate.

4.2.3 Hot pepper (*Capsicum sp*.)

Different types of hot pepper *(capsicum sp.)* are produced in Ethiopia. It varies in mode of growth and in fruit characteristics such as fruit size, shape, color and pungency. The degree of pungency varies considerably from very mild to hot. The fruits are erect or hanging, depending on the variety. Capsicums are important both as vegetable and spice crops. In Ethiopia bell pepper, chilies and hot pepper are produced for home consumption, industrial use and for export. It is also produced commercially as well as in home gardens but is mainly a small farmer and a rain fed crop grown in every region. The crop is mainly cross pollinated by insects (up to 90%). However, there are also some degrees of selfing. Hot peppers in general follow the breeding methods developed for cross pollinated crops.

Growth Requirement

Hot pepper (berbere) grows well under warm and humid conditions, but it requires dry weather at the time of maturity. It give best green fruit yield and better seed set at 21 to 27^{0}C during the day and 15 to 20°C at night. High temperature in combination with low humidity (40 to 50%) causes abscission of buds and flowers of poor fruit and subsequent low seed set. Hot pepper adapts well in sandy loam soil and well drained good clay loam.

Cultural Practices

The crop is produced under rain-fed and irrigation but it is commonly produced under rain-fed. About 500 to 700 of seed should be raised in nursery bed and transplanted to the field after 45 to 55 days. Appropriate spacing (60x40cm for rain-fed, and 80x30cm for irrigated), proper watering, manuring and proper weeding should be followed as a routine production practices. Hot pepper is susceptible for various diseases therefore; affected plants should not be used to produce seed. In addition, similar rotation pattern and proper sanitation to tomato should be used to avoid disease build up in the soil.

Isolation

It is necessary that different varieties grown for seed production are separated by a barrier for at least 200m. If seeds of different varieties are to be produced in a limited space, mainly for experimentation or basic seed production purpose, the seed can be obtained by enclosing a plant or group of plants in insect proof cages. However, under commercial seed production, it is better to concentrate on one or two standard varieties.

If optimum isolation is not possible, plant the crop on a large plot (at least 1 ha). And plant tall barrier crops such as sugarcane, maize or sorghum around the pepper plot to restrict the movement of bees into and out of the plot. Collect fruits only from the central part of the plot.

Harvesting and Processing

Pods will be ready for harvest in 5 to 6 months after transplanting depending on the variety. Harvest pepper fruits when their color indicates that they are ripe (usually red, but this varies depending on variety). The pods can be harvested through several hand pickings. Keep harvested fruits in a cool, dry place (25^{0}C and 50% relative humidity is ideal) for a week to allow any slightly immature fruits to ripen fully. Then they should be dried in the sun or on artificial batch for 10 to 15 days depending on the weather conditions. If you have more than one variety, keep fruits of each variety separated to avoid mixing the seeds during the seed extraction process.

Seed extraction: Sweet pepper seeds should be extracted from fresh fruits. *Chili* pepper seeds may be extracted from fresh fruits or from fruits that have been dried for 1 week at 40^{0}C. Seeds may be removed by hand or by grinding the fruits (with dull blades to minimize seed damage). Separate the seeds from fruits with a series of water washes. Further seed separation is done by winnowing or in a screen.

Seed drying: Spread the seeds on a screen for drying at 25^{0}C and 40% relative humidity for one week. In commercial condition the seed should be dried to low moisture (7 to 9%). Dry the seeds in a warm, well-ventilated placed out of direct sunlight. Stir the seeds occasionally and/or use a fan to hasten drying.

Seed yield: Depending on cultivars and conditions of cultivation average yield of 100 to 160 kg/ha seed can be obtained with germination percent of 90 to 96% 1000 seed weight of 6 to 7g.

Seed storage: Pepper seeds can be safely stored for at least 3-5 years. Place seeds in manila envelopes, cloth or mesh bags, plastic containers, or foil envelopes. The best containers are airtight, such as a sealed glass jar, metal can or foil envelope. Label each container carefully. Note the names of the hybrid and parents, the year, and any other information you feel is valuable. Store seeds in a cool, dry place. Small quantities can be kept in an air-tight container inside a refrigerator. For larger quantities, a special room with controlled humidity and temperature should be used. The temperatures should not exceed 20^{0}C and relative humidity (RH) in the storage area should not exceed 30%.

4.2.4 Carrot (Daucus carota L.)

Carrot (*Daucus carota, var. sativa*) belongs to the family *Umbelliferae*. It is a close relative to a wild species, commonly known as Queen Annes'slace. Carrot is a widely cultivated vegetable both under irrigation and rain-fed condition in Ethiopia. The roots arc either eaten raw or may be cooked. Carrot root contains β-carotenes, orange coloring matter of the root, and a prolific source of vitamin A.

Method of seed production

Production of carrot seeds is a two year project making it much more difficult than seed production of annual crops. Two types of seed production methods are available, i.e. seed-to-seed and root to-seed methods.

a. Seed to seed method

This method is practiced in areas where distinct cool season (for vernalization) and warm condition (for flower and seed development) is available. Seeds arc directly sown in seed beds of the permanent field of the same area where seed is produced. Early in the growing season plants should be thinned 10 cm apart. At usual harvest time for fresh market use, superior plants are thinned up to 75 cm apart. If the length of chilling period is long (above 10 weeks), dead or drying leaves must be removed and tops can be cut back at the usual harvest time of 5 cm to reduce transpiration and covered with mulch if necessary. When warm weather resumes, mulch is removed and leaves will re-grow and after several weeks a seeds talk will appear. Losses are very high with this method and off types cannot be eliminated since roots are not harvested and visually examined.

b. Root to seed method

In this method sound roots must first be produced. Then, these roots are harvested and off types discarded. The tops are trimmed back to 2- 4 cm, air dry until no surface moisture remains, and packed in paper bags with an equal volume of wood shaving (Sagatura) and placed in closed polyethylene bags at 2-5 °C. Better storage survival is realized if lateral and fibrous roots and senescing leaves are removed before storage. Vernalized roots should be planted during appropriate planting time. Care should be exercised to keep plants well watered. Seed stalk development will be evident in 4 - 6 weeks.

Conditions that stimulate flowering in carrot

Carrot roots require 6 - 8 weeks cold treatment (2-5°C) in root-to-seed method of seed production for floral induction. Cool growing conditions can reduce the cold storage requirement of carrot roots. At least 10 weeks of average temperature below 15 °C is required to stimulate flowering in seed to seed method of carrot seed production. Very low temperature is a common experience from October to January in cool highlands of Ethiopia. This low temperature stimulus creates favorable condition to the crops to flower and seed set. The warmer air temperature starting from February to Mid of September also favors seed maturity. Therefore, carrots seeds should be sown at the right time so that plants receive adequate vernalization.

Pollination and isolation distance

Individual carrot flowers are normally protandrous and much cross pollination occurs between plants in a seed crop. Cultivated carrots cross-pollinate very readily with the wild carrot. Precaution is, therefore, required to avoid out crossing with wild carrot. Because of the high chance of cross-pollination, isolation distances between different varieties of carrot should be a minimum of 800m. For basic seed production the isolation distance should be about 1600m.

Harvesting, seed processing and seed yield

The king or top-most umbel is the first to ripen. The seed will turn from a dark green to brown **(Fig.10)** and will actually begin to detach from the umbel, but because of the racemes, or little hooks that cover the seed, they latch together and stay with the umbel surface. Research results showed that early harvesting of carrot seeds before the seed is physiologically ripe results in lower seed quality. Carrot seeds should be harvested at the right time before the seed shatters. At this time, the umbels should be cut and placed into paper bags and stored in a cool, dry place for additional 2-3 weeks to allow the seeds to mature and dry completely. Then, spines will be removed by rubbing. Winnowing will be followed to clean the seeds. Seed is now ready to plant since carrot has no seed dormancy.

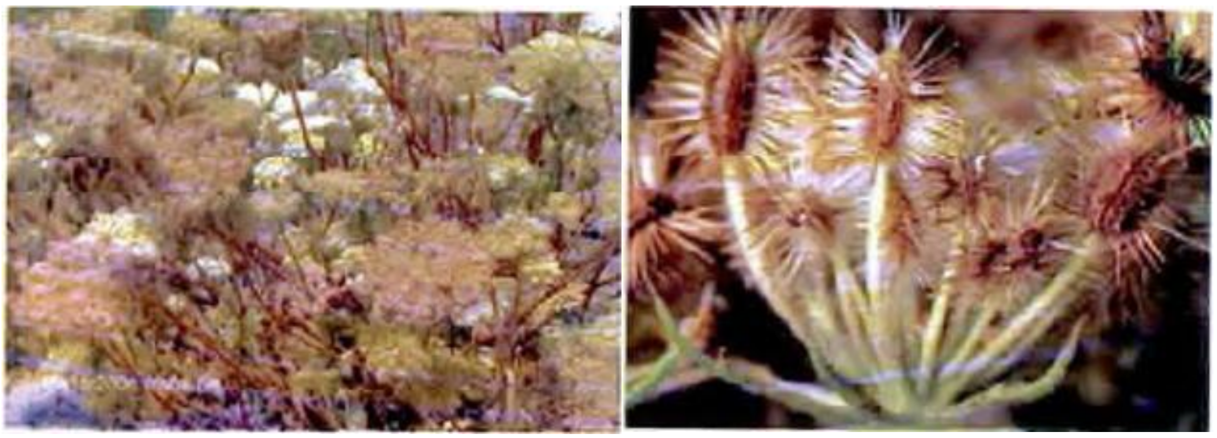


Figure 10. Carrot plant (left) and cluster of mature seeds (right)

Dry seeds should be stored in a moisture-proof container. Seed yield of carrot depends on varieties and locations. A good average seed crop can yield about 600 - 800 kg/ha seed. Research results indicated that good quality seed could be harvested on Nantes and Chantenay varieties. Carrot gave about 1000, 1070 and 586.20 kg/ha at Meraro, Lai Gaint and Ankober, respectively (Semagn *et* al., 2008).

4.2.5 Cabbage (*Brassica oleracea* L)

Head cabbage (*Brassica oleracea,* var. capitata) belongs to the family cruciferae. Cabbage is the most important Cole crop grown in Ethiopia. It has related types such as Brussels sprouts, broccoli, cauliflower, kale, kohlrabi and Chinese cabbage. The head cabbage (common cabbage) has a dense head of leaves, a short stem and additional edible leaves. The nutritional value of head cabbage is relatively high in vitamin C and A.

Climate: Cabbage is a hardy vegetable and is better adapted to the cooler regions. Usually largest and best quality of heads is produced during the cooler months of the year. Cabbage thrives best in cool and humid climate and can tolerate severe frost. It requires a dormant period of cool temperature to bolt and initiate seed stalks and flowers. Headed plants form seed stalks when exposed to mean temperature of about 5^0C for 6-8 weeks. However, for immature plants, such temperature is sufficient for two week.

Method of seed production

I. Seed to seed method (in-situ)

This method is used for areas where distinct cool season (for vernalization) and warm condition (for flower and seed development) is available. Seeds are sown in seed beds and the seedlings are transplanted to the permanent field of the same area where seed is produced. After the cabbage reaches maturity for fresh market use, mature heads should be incised. This method is usually practiced in temperate areas and very high altitude areas in the tropics or sub-tropics.

II. Head to seed method (ex-situ)

This method is used for areas where there is no suitable condition for flower and seed development. Seeds are sown and seedlings are transplanted as that of the first method. Mature heads are harvested and the stems are left in the field. After satisfactory exposure to low temperature for vernalization, the remaining plants are then transplanted to warm conditions of the mid altitude areas to accelerate flowering and seed maturity. The problem of cabbage seed production in Ethiopian highlands is that despite availability of sufficient low temperature in the first phase, sufficient condition is lacking in the second phase due to presence of rain fall and insufficient warm temperature for flowering and seed setting. Rainy conditions interfere pollination and cause self-rot and sclerotia rot resulting in poor seed quality. Thus, identifying the right sowing and transplanting dates is very crucial to the success of seed production in Ethiopia.

Pollination, isolation distance and selection

Cabbage is predominantly cross pollinated. Bees and diptera pollinate cabbage flowers. Cabbages can cross-pollinate easily with other Brassicas (broccoli, Brussels sprouts, kohlrabi, collards, cauliflower and kale). Therefore, sufficient isolation distance should be maintained for seed production. It is important to have greater isolation distance up to 1500 m between different types of Brassicas than between different cultivars of the same type (up to 1000 m). In addition to isolation, rouging should be done to keep trueness to type of the cultivars of cabbage and to produce healthy and vigorous seed. Rouging is done during planting out or before heading by checking for general foliage characteristics. Rouging is also done when heads have formed in the crop by checking head characters including shape, relative size and firmness.

Figure 11. Cabbage crop (left), flower and seed (right)

Harvesting, processing and Seed yield

It is necessary to harvest fully mature seed pods, as they will not mature any further after harvest. Since cabbage seeds shatter easily, harvesting is done carefully when 60- 70 % of the pods have turned brown and most of their inner seeds are light brown and firm **(Fig. 11** (right)). Harvested seed stalks are cured for 1-2 weeks. Pods are then threshed with sticks and sifted by hand. The smaller chaff can be separated simply by general winnowing. Seed is brittle and care should be taken not to crush during handling. Seed is dried in partial sun, and then stored in airtight container.

Seed yield of cabbage depends on growing conditions and varieties. A good average seed crop can yield about 700 kg/ha seed elsewhere in the world. About 580 kg/ha seed was recorded at Ankober, North Shewa, Ethiopia, during July sowing (Semagn et al., 2008).

Chapter Five

5. Seed Processing, Storage and Marketing

5.1 Seed processing

Proper post-harvest processing is critical to maximize yield, longevity, vigor, and overall quality of the seed crop. While production of vegetable seeds is similar in many respects to fresh market crop production, post-harvest practices require special skills and knowledge unique to seed production.

Seed lots received from the field are often at high moisture content and contain trash and other inert material, weed seeds, deteriorated and damaged seeds, off-size seeds, etc. **Seed processing** includes all steps involved in the preparation of harvested seed for marketing. It includes activities such as harvesting, threshing, seed cleaning and upgrading, seed enhancement, seed packing, handling and storage.

The objectives of seed processing include removal of a wide range of materials including plant and non-plant debris, seeds of other crops and weeds or unacceptable seeds of the same origin.

Seed processing involves a separate operation of threshing, drying, cleaning, treatment (dressing), grading, packaging, and labeling.

5.1.1 Threshing

Threshing involves separating the seed from panicles and straw by hand, animals or machines. In all the techniques care must be taken to minimize physical damage, which can affect germination or allow disease infestation.

5.1.2 Seed Drying

It is necessary to dry seeds before or after seed cleaning and before storage and packing since seed drying enhances seeds to have longer storage life and prevents occurrence of diseases and pests. The rate at which a seed lot can be dried depends on the packing character of crops and the initial moisture content of the seed. Lettuce is generally considered to be relatively quick drier; carrot, beetroot and Swiss chard medium driers; but cabbage is slow drier.

Determining seed moisture content:
The most important factor influencing seed viability during storage is the moisture content and the rate of deterioration increases as the seed moisture content increases. It is important to harvest mature, relatively dry seeds or to reduce the moisture content of high-moisture seeds soon after harvest. The drier the seed the higher will be the storage life. Moisture content of seed is defined by the International Seed Testing Association (ISTA) according to the following formula:

$$\text{Seed Moisture Content (\%)} = \frac{\text{Fresh Seed Weight} - \text{Dry Seed Weight}}{\text{Dry Seed Weight}} \times 100$$

In order to determine the percent moisture content of fresh seed, a sample of fresh seed is weighed, and then an equal weight of fresh seed is dried slowly to remove the moisture, and then re-weighed.

Seed drying methods

Generally, there are three main methods of drying seed in sub-Saharan Africa. These are sun drying, natural forced air-drying and artificial drying.

1. Sun or shade drying

The seed is spread on floor, racks, mats etc. in the sun or shade to dry. It is important to dry seeds on a waterproof base to avoid transfer of moisture from the ground up to into the seeds. This method relies solely on ambient conditions, which can dry or increase the seed moisture content depending on wind, temperature and relative humidity. Drying is faster in well-ventilated areas.

Advantages

- Small quantities of seed can usually be quickly and efficiently dried in the shade
- It is inexpensive and requires minimal supervision or attention to the seeds (turning every 1-2 hrs)

Disadvantages

- Weather dependent
- Incomplete drying in humid environment
- Some crop seeds are unable to withstand the high temperature in direct sunlight
- Unless screened from wind, seed can be blown away and lost or mixed with others.

2. Natural forced air-drying (ventilation drying)

Natural air driers are constructed to take advantage of ventilation. Seeds are spread in thin layers on bed, which can be horizontally oriented. Supporting beds are made of perforated materials (sacking, wood or metal sieves) which permit air movement through the drying seeds. The drier is oriented with the prevailing wind direction and works on the principle of hot air rising, which removes the moisture.

Advantage

- Use natural but ambient air
- Local materials can be used for the constructions of ventilated driers

Disadvantage

- Weather dependent
- Not situated for use in the humid tropics

3. Artificial drying

Larger quantities of seed can be dried using the artificial method. This method allows early harvesting of seed crops so that shattering and the possibility of weather damage are minimized. Artificial drying equipment relies on increasing the airflow around the seed, with or without dehumidification of the air by heating or using chemical desiccants. Artificial drying facility should consist of the following:

- A fan of sufficient size to deliver a minimum dry air flow
- Efficient heating capacity to raise the air temperature to 35-40^{0}C
- Adequate control to maintain the air temperature at 35-40^{0}C or less
- Adequate drying capacity compatible with the harvesting rate at which seeds will be received by the plan

Advantages

- Large quantity of seed can be dried
- Allows early harvesting of seed crop
- Provide better control of seed quality in all environments
- Independent of weather conditions

Disadvantages

- Equipment dependent
- Expensive equipment out of the reach of smallholders
- Difficult equipment to clean with a risk of seed contamination between seed lots

5.1.3 Seed Cleaning

It is the removal of inert matter, other crop seeds (including weeds), and damaged seed from harvested, threshed and dried material to increase marketable value. Cleaning ensures good seed quality. If done with right equipment and appropriate methods, it can increase purity and germination by removal of unwanted materials. It can also decrease the number of diseased seeds and improves the visual, commercial and planting quality of the seed lot. Seed cleaning can be done manually by sorting out unwanted material from small seed lots.

The physical differences such as relative size, shape, length, density, surface texture, color, affinity to liquids can be used for seed cleaning. Seed cleaning based on relative size and density are indicated below.

Separation based on weight (or specific gravity)

Cleaning seeds by differences in specific gravity is one of the oldest seed cleaning techniques. Winnowing is the process of separating the seed from the chaff or pod. On the simplest scale, seed and materials are dropped before a wind source (either natural wind or a fan). The heavier materials fall closer to the wind source while lighter materials are carried further from the wind source. On a small-to-medium scale this is a very effective method to quickly clean seed. Many screen cleaners have a fan to assist in blowing off some dust and chaff.

Separation based on size

Screens with various hole sizes are commonly used to separate seeds based on size either by hand or by machine. Screens are used to either permit the crop seed to pass through the screen (collect and discard material larger than the seed that does not pass through), or to retain the crop seed on top of the screen and permit smaller-sized materials to pass through and be discarded. Hand-held screens are very useful for small to medium scale seed cleaning.

5.1.4 Seed Treatment

Seed treatment commonly refers to the application of pesticides (fungicides, insecticides, or a combination of both) to seeds to disinfect and disinfest them from various seed born and soil born pathogenic organisms and storage insect pests. After cleaning, seed must be treated for several different purposes;

- Seed disinfection to combat seed borne diseases and insect pests.

- Protection of seeds against diseases and pests that may be present in soil or be air born when seedlings emerge.
- Specialized seed treatments such as seed coating, pelleting, scarification, blending, delinting (cotton), to protect seeds against pests or aid in germination.

Seed disinfection - elimination of a pathogen which has penetrated into living cells of the seed, infected it and become established.
Seed disinfestations - the control of spores and other forms of pathogenic organisms found on the surface of the seed.

Method of Seed Treatment

There are three seed treatment methods: mechanical, physical and chemical methods.

1. Mechanical methods: are designed to remove infectious materials mixed with seeds. Seeds can be mechanically cleaned before sowing to remove most pathogenic organisms from the seed surface. Mechanically treated seed is not completely free from pathogens and requires further treatment.

2. Physical methods**:** are used primarily to kill pathogens rooted deep in to the seeds. Physical methods include hot water and soak water treatments and ultraviolet, infrared, x-ray and other types of irradiation. Physical methods, however, do not protect seeds against soil born organisms; they are effective only against pathogens present on or in the seeds. In all water soaked methods, seeds are soaked in water for about 2 hrs and kept under anaerobic conditions for one or more days. In some cases seeds are soaked for 64 hrs in water at about 22.2^{o}C and then dried.

3. Chemical methods (seed dressing): applied to protect stored seed through the distribution chain and during the early stages of crop growth. Seed dressing is a more general used term and includes insecticide/fungicide treatment, pelleting, priming and rhizobium inoculation. Pelleting is done for precision planting of small-seeded crops, chemical can be included. Pelleting results in early and homogenous germination of the seed thus ensuring an even emergence after planting. Rhizobium inoculation normally is done just before planting and is of important mainly for legumes crops. Insecticidal and fungicidal seed dressings should act against seed-borne diseases, storage pests and fungi, and soil-borne pests and diseases that attack the seeding and the plant in the later growth stages. Ideally, the chemical used as fungicide/insecticide should combine the following characteristics:
    - ✓ Effective against all the major pathogenic organisms;
    - ✓ Non-toxic to the plant and people, if misused
    - ✓ Environmental safe (persistence)
    - ✓ Stable during the storage period
    - ✓ Systematic in the plant to increase its effective life
    - ✓ Economically competitive

5.1.5 Seed Grading

The objective of seed grading is to produce sound even-sized and uniformly shaped seed for ease of mechanical planting. It also improves the appearance of processed seed which increase sales appeal. Most seed cleaning machines simultaneously grade the seed into first grade, second grade, etc, based on uniform size and shape.

5.1.6. Seed Packing

At the end of processing, the seed is packed and sealed into containers of uniform size. The package must be able to protect the seed from physical (cracking, bursting), climatic (rainfall, light, temperature) and biological (disease and pests) damage. The package therefore serves as a:

- Convenient unit of handling, purchase, transport and storage
- Protection against contamination, mechanical damage and loss
- Suitable environment for storage
- Sales promoter (information and advertisement)

5.1.7 Seed labeling

After packing some information about the contents of a package must be displayed. This includes:

- The name of the species (crop name)
- The cultivar
- The grade and the lot reference number
- Date of sealing
- Production year and season
- Minimum germination %
- Quantity

5.2 Seed Storage

When seed processing is completed it is necessary to keep the seed under the best possible conditions to ensure that the maximum potential germination and other seed quality factors are maintained. The storage life of seeds is dependent on natural longevity of seeds which varies between crop types, maturity at harvest, storage temperature and relative humidity, moisture content of seeds, harvesting and processing conditions, and mechanical damages on the seeds. Temperature and relative humidity are the two most important factors that can affect seed quality in seed storage. The reduction of seed viability is slower at lower temperature. As a ‘rule of thumb’, for every rise of 5°C in the range of 0 to 40^0C, seed life is reduced by half, though there is a great variation between species. Relative humidity is also another main factor which affects the storage life of vegetable seeds. High humidity levels cause seeds to increase their respiration rate and use their storage energy. Furthermore, the incidence of storage fungi and insect pests will be increased with the increase in relative humidity. Thus, the seeds should be dried (5- 8 %) depending on type of crops **(Table 3)** before storage and they need to be stored in air tight containers.

Table 3. Satisfactory moisture level of seeds to be stored. Source; Semagn *et.al (*2010)

Vegetable types	Maximum seed moisture (%)
Cabbage and other brassicas	5
Carrot, parsnip, parsley	7
Beetroot and swiss chard	7.5
Spinach	8
Lettuce	5.5

It is also possible to keep the seeds longer. But germination capacity will be progressively lowered. Exposure to sun light and mechanical damage on seeds is also important factors which contribute to shorten the storage life of vegetable seeds.

Table 4. Life expectancy of vegetable seeds under favorable storage condition

Vegetable types	Years
Beetroot, Cabbage, Cauliflower, Swiss chard	4
Carrot, Chinese cabbage, kohl rabi	3
Lettuce	6
Radish	5

Source; Semagn *et.al,* 2010

6.3 Seed Marketing and Distribution

Marketing is an activity directed at satisfying needs and wants through the exchange process. Seed marketing is one of the key components in seed industry which protects the interest of all parties (breeders, seed producers, seed distributors and farmers) involved in seed business. Seed is a perishable commodity, expensive to produce, to store and transport and therefore, production must be geared to realistic marketing and distribution targets. There are four basic components in seed marketing:

Producer: Seed producing, processing and distributing organizations

Product: Seed is delicate component and vulnerable to damage by temperature, moisture chemical and biotic stresses and need careful handling in production, processing, storage and distribution. The value of the seed cannot be assessed only by sight.

Customer: Vital to understand behavior of the target group, with regard to adoption of new technology and focusing on the interest of end users. For marketing to be successful, it must be oriented to the needs of the customer (farmers). If the farmer does not believe the seed is best suitable to his needs, there will be no seed demand.

Competitor: Any other seed producing and supplying agencies. For example farmers can compete with the given seed enterprises through home-saved seed or locally bartered seed. Thus, there is a need to offer seed of a higher quality, in right place, right quantity, at right time and acceptable price.

6.3.1 Seed marketing activities

Generally, there are about six seed marketing activities.

- Establishment of marketing strategy
- Determination of consumers' needs
- Accumulation of seed to satisfy needs
- Communication with potential consumers
- Setting appropriate price
- Seed selling & distribution of seed to the consumer

Marketing strategy

Seed marketing strategy is long or short term plan regarding the different activities of the seed company related to market or marketing itself. It is establishment of effective marketing policies on production planning, distribution chain, market promotion activities and seed processing policy. A major function of seed marketing is to facilitate the flow of seeds from the point of production to the consumers (farmers). In seed enterprises that have both seed production and marketing units the accumulation of stocks rests primarily with the production section. However, the marketing section communicates anticipated requirements (kind, variety, quantity and quality of seed needed) to the production section far enough in advances of the growing season to permit the seed to be produced and prepared for marketing. As the seed is prepared, the production section informs the marketing section of the exact quantity and quality of teach variety available.

6.3.2 Seed marketing research/study

It is a continuous and systematic determination of consumers demand. Market demand is the total volume a seed that will be bought by consumers in defined location within specific period and certain marketing efforts such as promotion activities and market information. It used to analysis the prospective market with regard to potential customers and competitors. Therefore, assessment of effective seed requirement is crucial to any planned seed programs. The underlying principle in marketing demand forecast should be that the seed supply keeps pace with seed demand (both present and future) in terms of quantity, quality, price, place and time. The outcome of such an approach would be planned seed production and marketing. It would also avoid shortage and glut and as well ensure stable prices and profits.

In marketing demand forecast, the following factors must be considered carefully.

- Who are the customers- seed market target groups
- Their geographical location- where about, accessibility for marketing
- Total cultivated area, seed rate, quality replacement period and assessment of total potential seed requirements of each of the important seed
- Impact of extension efforts on the introduction of improved production techniques, and future plans for promotion.
- Current area of land under high yielding varieties and amount of seed sold in the last years
- Cultivar preference, package size, kind of packaging, quality and price
- Number and size of competitors
- Kinds of publicity and sale promotion that are most effective
- Climate of the area where seed is being marketed

6.3.3 Seed Pricing

A seed enterprise should set the price for certified seed based on total cost of seed production. Generally, high quality seed should be priced higher than grain.

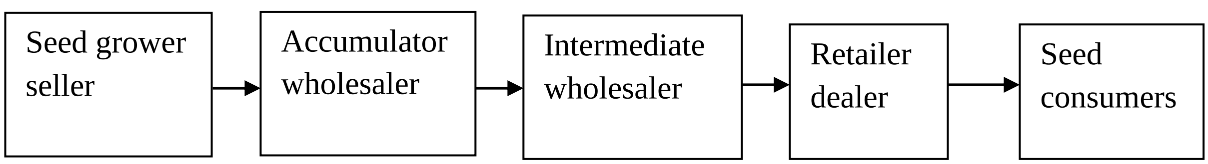
Factors to be considered in price setting for certified seed:

1. Mating system of the crop- high price is set for cross pollinated seed than self-pollinated one.
2. Seed rate- high price is set for low seed rate crops than high seed rate one
3. Multiplicative factors of the crop- high price is set for high multiplicative seeds than low multiplicative crops

4. Level of market orientation of crop production- high price for commercial crops than noncommercial one
5. Crop specific factors:
   - Difficulty to store as vegetable and fruits
   - Difficulty to produce seed
   - High incidence of seed transmitted disease
   - Specific advantage of seed treatment such as insecticides, fungicides, inoculants, primers etc.

6.3.4 Seed distribution and selling

Seed distribution and selling complete the process that converts the physical and biological properties of seed produced to economic value for the sellers. Seed distribution is a function of marketing channels and logistic costs. Seeds pass from the producers to the users through marketing channels. The key success in seed marketing is the establishment of effective channel of distribution. The various channels through which seed can be marketed vary greatly according to the needs of the seed company. Distribution has to be arranged so as to deliver the right quantity of seed of the right quality at right time (usually before planting) with reasonable prices. Since producers can sell directly to final customers, they must feel that they gain certain advantage by following the marketing channels.



Arrangement of seed distribution chains with whole seller retailer network has the following benefits;

- ✓ Timely delivery- consideration of peak demand time such as planting time, proximity to target group
- ✓ Selling initially set price
- ✓ More effective than direct distribution by producers- addressing large number of customers and increase market efficiency
- ✓ Feedback mechanism for establishing market demand
- ✓ Cost effective for both seller and buyer- share financial load of logistic costs

There are five types of seed distribution systems in Ethiopia

- Farmer to farmer seed distribution
- seed enterprise (public and private)
- co-operatives
- ministry (bureau) of agriculture
- non – governmental organization

Chapter Six

6. Seed Quality and Seed Testing

6.1 Seed Quality

Seed quality is the sum of all properties contributing to seed performance. It is one of the main factors affecting crop production potential. For seed to play a catalytic role in crop production, it should reach farmers in good quality. High quality seed can be defined as seed of an adapted variety with high varietal, species, and physical purity; high germination and vigor; free from seed borne pests; and properly cleaned, treated, tested and labeled.

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

- Genetic seed quality: the inherent genetic make-up of the variety contained in the seed, which provides the potential for higher yield, better grain quality, and greater tolerance to biotic or abiotic stresses. It is determined by those plant characteristics that result from the genetic potential of the embryo. Plant breeders through selection, introduction and hybridization using conventional or modern biotechnological tools develop new crop varieties for use. The gene and combinations of genes constituted in the variety define the genetic seed quality and therefore, its potential attributes such as grain yield and other agronomic characteristics.
- Physiological seed quality: the viability, germination and vigor of seed, which determines the potential germination and subsequent seedling emergence and crop establishment in the field.
- Physical seed quality: free from contamination with other crops, common and particularly noxious and parasitic weed seeds, seed size, seed weight and seed lot uniformity.
- Health quality (sanitary seed quality): absence of infection/infestation with seed-borne pests (fungi, bacteria, viruses, nematodes, insects, etc.).

6.2 Seed Testing

Seed testing is a science of evaluating the seed quality to determine its value for planting purpose. Objectives of seed testing;

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

☞ Seed testing is done to assess the physical (analytical), physiological and sanitary quality of the seed.

Seed sampling

Seed sampling is important since it is physically and financially impossible to examine large number of seeds, a representative portion of the population is taken and examined; the portion is called sample. Seed sampling and testing is part of the seed procurement process but it may also be used by emergency staff and local officials to verify the quality of seed before delivery to farmers or if the seed has been stored for several months.

The International Seed Testing Association (ISTA) has established regulations and procedures for sampling of seed. In the seed industry seed lots are assumed to be reasonably uniform, that is homogenous rather than heterogeneous though it is difficult to make this assumption. Therefore, sufficient sampling to obtaining a representative sample is extremely important.

In sampling a seed lot, a method of sequential sampling is used:

a) **Primary samples** are taken from either different containers (bags) or different locations if the seed is in bulk.
b) Primary samples are combined and mixed to form a **composite sample**.
c) Normally the composite sample is thoroughly mixed and mechanically divided in a sequential manner to obtain the size of the **submitted sample** recommended by ISTA. The submitted sample is the sample from which the **working sample** is derived for testing and evaluation **(Fig.12).**

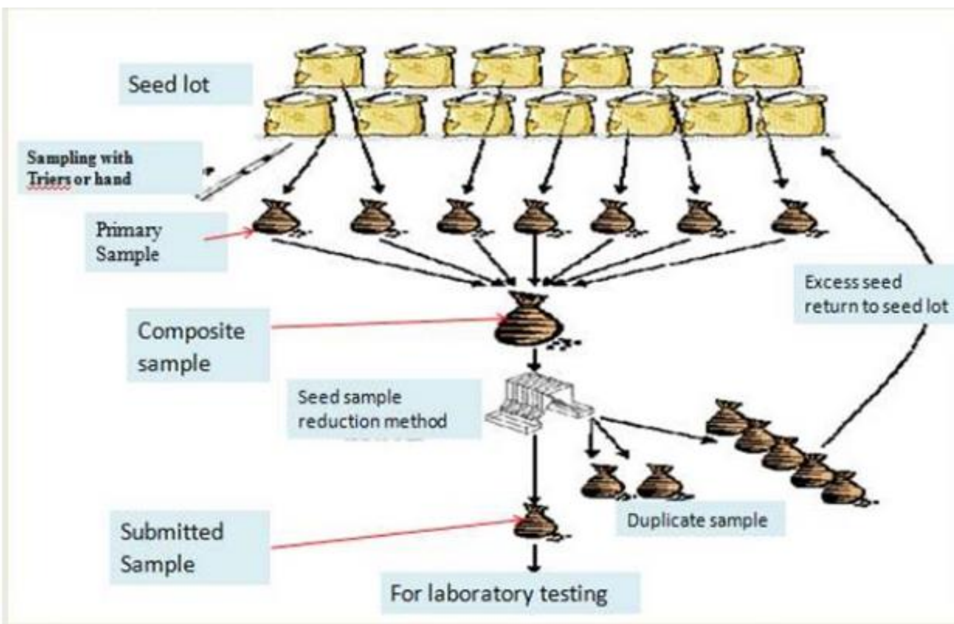


Figure 12. Seed sampling methodology

The major seed tests include:

- Physical purity analysis
- Seed moisture analysis
- Germination test
- Viability test
- Seed health test
- Seed vigor test
- Varietals (cultivar) purity test

6.2.1 Physical purity analysis

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

- **Pure seed**: including any seed fragments that are larger than half the size of a whole seed. Immature, shriveled and diseased seeds are regarded as pure seed, if they can be identified as the species stated
- **Other crop seed**: they refer to any kind of seed or seed like structure of any plant species other than of the pure seed
- **Inert matter**: including any other materials (soil, stones, chaffs, stems, leave etc) and seed like structure from both crop and weed plants. Any seed fragments that are less than half-seed sized also considered as inert matter.

6.2.2 Seed moisture content analysis

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

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

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

$$\text{Moisture content (\%)} = \frac{\text{Loss of weight}}{\text{Initial weight of seed}}$$

6.2.3 Germination test

The main objective of seed germination test is to obtain information about the field planting value of the seed lot. Germination in a laboratory refers to the emergence and development of those essential structures from the seed embryo for which seed being tested. It indicates the ability of the seed develop into a normal plant under favorable conditions in the soil.

Procedures

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

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

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

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

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

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

III. **Hard seed**: seeds that has not absorbed water

IV. **Fresh un-germinated seed**: dormant seed that absorbed water and maintained its fresh condition i.e. is not discolored or moldy and has a firm turgid texture.

V. **Dead seed**: that has absorbed water and a soft, non-turgid texture discolored and is often moldy.

6.2.4 Seed viability test

Seed viability (germination potential) means that the seed is capable to germination and producing a normal seedling. In other words, viability of a seed is the state of being aliveness, metabolically active and possesses enzymes capable of catalyzing metabolic reactions needed for germination and seedling growth.

A germination test is usually the best method for estimation seed viability. However, all viable seeds may or may not germinate because of the seed may dormant, hard seed or slow germinating seed. In such cases, it is necessary to carry out a viability test on the seeds, which remain un-germinated at the end of the test.

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

The tetrazolium test distinguishes between viable and dead tissues of the embryo on the basis of their relative respiration rate in the hydrated state. Although many enzymes are active during respiration, the test utilizes the activity of *dehydrogenase* enzymes as an index to the respiration rate and seed viability. Dehydrogenase enzymes react with substrates and releases hydrogen ions to the oxidized, colorless, tetrazolium salt solution, which is changed in to red *formazan*as it is reduced by hydrogen ions. Seed viability is interpreted according to the topographical staining pattern of the embryo and the intensity of the coloration.

Procedures

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

Advantages of TTC test

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

Disadvantages of TTC test

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

6.2.5 Seed health test

Seeds can be carry seed-borne pathogens such as viruses, bacteria, fungi and nematodes. Some of these are transmitted; i.e. the seed-borne disease can indeed affect the germination seedling or the resultant plant.

Seed health testing can check on the effect of these measures and can be especially useful in preventing the introduction of new pathogen into an area. The health testing method should be simple, cheap, and quick and should facilitate identification of the pathogens. Seed health testing may be done by visual assessment or followed more advanced seed health testing. Visual assessment is by observing the presence of sclerotic, spots on seeds. The more advanced seed health testing includes:

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

6.2.6 Seed vigor test

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

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

Due to variations in seed vigor, seed lots with similar germinations may respond differently when subjected to adverse field conditions. Generally, high germination capacity is believed to be associated with high vigor, and low germinated must be rejected since field emergence is reduced drastically and cannot be compensated by increasing seed rates.

6.2.7 Varietal purity test

Varietal purity refers to whether a variety is true-to-type and if it is still has the original genetic make-up. For pure line varieties, all plants are similar in morphological, physiological, cytological and chemical characters. Varietal purity tests establish whether a field or a seed lot of a variety is sufficiently pure, i.e. whether a sufficiently large percentage of seed, seedlings or mature plants conform to the original description of the variety. It can be controlled by inspection of plants in seed multiplication fields or examining seeds or seedling in the laboratory or growing plants in field plots.

6.3 Seed Germination and Dormancy

6.3.1 Seed Germination physiology

Physiological changes during germination:

- *Imbibition*: during imbibition, the dry seed coat become softened and more permeable to water and gaseous, which result into swelling of the seed.
- *Digestion*: the stored food materials in the seed need to break down through digestion before it can be used in the germination process. Starches are digested to sugar, fats to fatty acid and the proteins to amino acid used in respiration during seed germination
- *Respiration*: respiration takes place in all living cells. During germination, the respiration rate is high. Energy is mainly librated from carbohydrate. The proteins are used mainly in constructive metabolism.
- *Emergence of essential structures*: the radicle emerges usually through the micropyle. Some seeds possess structures and secrete substances, which aid in removing the seed coat during germination.

Germination can be categorized into two based on the fate of the cotyledon or storage organs.

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

b. **Epigeal germination:** the hypocotyl elongates and pushes the epicotyls and cotyledons above the ground and leaving the remainder of the seed below the surface.

Conditions necessary for germination;

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

- **Suitable temperature**: the minimum, optimum and the maximum temperature for germination of seed vary from species to species.
- **Suitable composition of atmospheric gaseous**: aeration of the soil is essential for germination. The process of germination is related to living cells and requires an expenditure of energy. Oxygen is necessary for aerobic respiration by which the seed gets the requisite energy for the growth of the embryo.
- **Light for certain seed species**: light is not indispensable for the germination of seeds. Seeds can germinate well even in total darkness. However, most seeds germinate better when they exposed to light.

6.3.2 Seed Dormancy

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

Types of seed dormancy

Different types of seed dormancy are recognized according to the origin of dormancy such as property of the outer coverings of the embryo, morphological condition of the embryo, physiological conditions of the embryo, and combinations.

Dormancy may be primary or secondary.

A. Primary Dormancy: divided into two

- Exogenous dormancy
- Endogenous dormancy

i. Exogenous dormancy

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

This form of dormancy is related to the physical properties of the seed coat including impermeability to water, low permeability to gases, and mechanical restriction of embryo growth.

1. Impermeability of seed coat to water

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

2. Low permeability of seed coat to gases

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

3. Mechanical restriction of the embryo growth

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

ii. Endogenous dormancy

It is caused mainly due to the inherent property of the seed. It is caused by:

1. Morphological dormancy

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

2. Physiological dormancy

This type of dormancy caused due to;

a. Presence of inhibitor and absence of promoter; the dormancy may be caused by a result of the absence of growth promoters and the presence of growth inhibitors. For example, gibberellins present for seed germination to occur and cytokines can prevent this expression.
b. Osmotic inhibitors; substances possessing high osmotic potential can inhibit the germination of seed. Sugar and salt compounds in sufficient concentration may compete with seed for water and as a result, the seed never becomes fully imbibed and thus remain un-germinated. E.g. Fruit seeds of palm and peach trees.
c. Metabolic inhibitors; certain compounds present in the seed may inhibit specific metabolic pathways. For example, Cyanide (CN_3) inhibits seed germination through their effect on respiration. Phenolic compounds (caumarin) can also inhibit seed germination and widely occurred in agricultural seed and regarded as natural germination inhibitors. Abscises acid (ABA) inhibit the enzyme syntheses that are important in the early stages of germination.

B. Secondary seed dormancy

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

Method of overcoming seed dormancy

1. Scarification: mechanical or chemical treatments that weakens or rapture the hard seed coat

a. Mechanical scarification

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

b. Chemical scarification

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

2. Stratifications: When dormancy is due to endogenous factors (embryo development or presence of inhibitors), seed is subjected to stratification, i.e. incubation of seed at low temperature (0-5^{0}C) over a moist substratum for 5-10 days (to break dormancy) before placing it at optimum temperature for germination. Some seed may require prolonged stratification (2-6months at 5-10^{0}C).

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

4. Treatment with growth regulators and other chemicals: Different groups of chemical have been reported to break dormancy. GA_3 is the widely used chemical and found to be most effective in breaking dormancy. Potassium nitrate (0.2%) has also been found to be effective in breaking dormancy.

Chapter Seven

7. Variety Development, Seed Certification and Legislation

7.1 Variety Development and Evaluation

Modern varieties are the backbone of the formal seed industry. In Ethiopia, variety development for major crops began in 1966 with establishment of EIAR. It is a principal plant breeding institution, undertaking responsibilities for cereals, legumes, oil seeds, fibers, horticultural and forage crops. Apart from EIAR, Universities are also involved in agricultural research and variety development. The Ethiopian Pioneer Hybrid International (EPHI) introduces and tests maize hybrids from parent company for adaptation and release in Ethiopia.

A cultivar/variety is a population of individuals known to have certain morphological, physiological, cytological, and chemical and other characteristics which remain stable from generation to generation when reproduced sexually or asexually. New variety can be developed through established breeding programs such as;

a) **Selection**: consists of selecting the most promising plants from a heterogeneous or mixed population on the basis of phenotype, their seeds are bulked and used to grow the next generation.
b) **Varietal introduction**: varieties that have proved themselves elsewhere under similar climatic conditions are imported and introduced.
c) **Hybridization**: refers to crossing between genetically dissimilar plants of the same species. It involves planned crosses and subsequent selection of desired plants from the segregating populations to combine the most desirable characteristics of two or more varieties

The new varieties must pass through a series of evaluation, release and registration tests and procedures before farmers can use them for commercial production. The variety development, evaluation, release and registration procedures pass through several stages as follows:

a. ***Station trial or observation nursery:*** New introductions or advanced lines are grown in 1-2 observations rows and compared with checks and observations recorded for agronomic characters, reactions to disease and yield.
b. ***Preliminary Yield Trial (PYT*)**:** One hundred or more entries are evaluated each year. Each entry is grown in a 4-6 row plot of 2.5 m (in more than one site) using an augmented design along check varieties. Data is recorded and statistically analyzed.
c. ***Pre-National Yield Trial (Pre-NYT*):** About 25 varieties and two checks are compared. Each variety is grown in a six row plot of 2.5 m at four or more locations. An RCBD design with three replications and recommended packages are used. Field data recorded and the yield analyzed statistically where 50-70% of the entries advanced to national yield trial *(NYT)*.
d. ***National Yield Trial (NYT):*** Similar procedures are used as Pre-NYT, but with four replications and more test locations and years. After three years of testing, the promising lines are identified for submission to NVRC.

e. ***Farm Verification Trial (FVT):*** Promising lines are evaluated on large plots (100m^2) on farmers' fields where the new varieties are intended for release. The NVRC visits the trials and make its own assessment.

7.2 Variety Release and Registration

The variety release and registration system has evolved over a number of years. Since1984 variety release and registration has become the responsibility of the National Variety Release Committee (NVRC). The Committee is composed of breeders (4), agronomists (1), crop protection specialists (2), research/extension (1) and socio-economists (1) representing different research institution and user organizations. The membership includes the EIAR, Ethiopian Biodiversity Institute (EBI), Ministry of Agriculture (MoA) and others.

Varieties are in extensive trials before they are proposed for release at regional or national level. Breeders carry out a minimum of two to three year national or regional trials (NYTs) in at least three to five locations or different agro-ecological zones before submitting an application to NVRC. The variety should be tested for yield, tolerance to pests and other important agronomic characters compared with standard varieties or local check. Superiority in yield, grain quality and acceptable level of distinctness, uniformity and stability are required to grant a release.

Breeders and the crop team leaders should consult with appropriate team members, extension and on-farm research personnel before preparing a proposal for variety release. A complete data of the promising variety proposed for release must be submitted to NVRC for review and approval. The varieties submitted to NVRC will further be evaluated for one season in on-farm verification trials under farmer management practices before a final release.

The NVRC appoints a sub-committee composed of NVRC members and other specialists to report on variety performance after examining the data and field visits. The report covers performance data evaluation, field performance evaluation and recommendations for the NVRC. The Committee may release a variety not only on superior yield, but important characters such as grain color, early maturity, etc. compared to existing commercial varieties. Upon the release of the new variety breeders will provide small quantity of seed to the chairman of the NVRC who will forward it to the EBI for the long-term storage.

7.3 Seed Certification and Legislation

7.3.1 Seed Certification

Seed certification is a program to maintain and make available high-quality seeds and propagating materials of genetically distinct crop varieties to the farmers. Certification is an officially recognized method for maintaining varietal identity of seed on the open market. Seed certification procedures are designed to ensure genetic purity (trueness-to variety), physical purity, good germination, seed health and moisture content of the certified seed.

Legally sanctioned certification systems operate in many countries, under various systems. The Organization for Economic Cooperation and Development (OECD), international seed certifying agency, has developed standards, schemes and guide relating to varietal certification of several crop seeds moving in international market. The objectives are:

1) To establish minimum standards for genetic purity and recommend minimum standards for the classes of certified seed
2) To standardize seed certification regulations and procedures
3) To encourage the use of seed of high quality in the participating countries and to facilitate movement of quality seed among the countries
4) To assist its member agencies in seed promotion, production and distribution. In line to OECD, different countries establish their own local seed certifying agencies which is responsible for seed certification. Accordingly, seed certification in Ethiopia is done by the Agricultural Inputs Certification Department (AICD) of the ministry of agriculture and Rural Development. Other international organizations aims to facilitate the seed certification are; The International Seed Testing Association (ISTA), designs uniform seed-testing methods and grants licenses to laboratories that meet its standards and The Union for the Protection of New Varieties of Plants (UPOV) established to promote plant variety protection and to release uniform legislation in this field.

Seed certification is a system that incorporates certain basic steps. The main techniques applied in seed certification are:

1. Eligibility of Varieties

a) **Value for cultivation and use (VCU**); determination of agricultural value of new varieties compared to existing commercial varieties in different agro-ecological zones across seasons
b) **Distinctness, uniformity and stability (DUS) tests;** Tests carried out to determine whether or not a new variety is sufficiently distinct from all other varieties and sufficiently uniform and stable

2. Seed Classes

Classes, as well as the maximum number of multiplication in each class, are set for each species. The number of generations used in the certification system is fixed at the lowest possible level because the genetic value of a seed crop can decrease from one generation to another. The breeder class has to be considered the maximum obtainable genetic purity level. Restricting the number of generations is one way to preserve quality. This is more important with cross-pollinating than self-pollinating crops. Different seed classes are labeled with differently colored labels for easy identifications.

3. Seed Quality Standards

Standards are set for field inspection (including varietal purity/off-type count), isolation from potentially contaminating crops and permitted disease and weed, seed testing and pre- and post-harvest quality standards. Seed field that fail to reach these standards are either down-graded or rejected for seed purposes.

Table 5. Seed certification standards

Factor	Breeder	Basic	Certified
Purity (min)	98%	96%	94%

Inert matter (max)	2%	2%	4%
Other crop seeds (max)	0%	0.01%	0.02%
Other varieties (max)	0.04%	0.2%	0.5%
Germination (min)	85%	80%	70%

Only varieties which have been officially evaluated and satisfy minimum quality standards can be marketed.

4. Field Inspection

The main objective of field inspection is to ascertain that the seed being produced is of the notified variety not contaminated both physically and genetically beyond certain specified limit.

This is done during various visits to each seed field during the cropping season. Especially:

- Before sowing: cropping history and general suitability of the field, variety and generation of seed to planted;
- At flowering: off-types, isolation and cultural practices;
- Before harvesting: final check on the field and yield estimate; and
- After harvesting: threshing, storage, sampling, and affixing transport labels

The objective are achieved by verifying that the seed crop is;-

- Field meets the prescribed land requirement
- Seed used for raising seed crop is from approved source
- Provided with proper isolation or border rows in hybrid seed production
- Planting ratio in hybrid seed production is followed
- Properly rogued in contamination with standard for different factors
- True to varieties characteristics and no mechanical mixture, proper harvesting

Crop stages for field inspection: the number of inspection and growth stage depends upon crop duration, mode of pollination, possibilities of contamination, nature of contamination factor and stage of disease susceptibility. In sexually propagated crops, the convenient stages of growth are; pre flowering, flowering, post flowering / at maturity, at harvesting

Observation during field inspection: off-types, objectionable weed plant, inseparable other crop plant, diseased plant, pollen shedder and shedding tassel

5. Seed inspection

After the seed has been cleaned, samples are taken to check quality. Upon sampling, the homogeneity of the seed lot is assessed, and other aspects such as correct labeling, lot number, etc. are checked. The sample is immediately dispatched to the seed testing station, where, according to the International Seed Testing Association rules (ISTA), tests are carried out for: physical purity, germination, moisture, varietals purity and seed health. Other tests (e.g. vigor test, viability test, 1000 grain weight test) are often carried out.

6. Labels

Certification labels are put on every seed container indicates that the seed has met the minimum certification and seed testing standards. A lot number is given to any such thoroughly mixed blend which states the variety, crop name, season of production, seed class, growers, seed test data, date of sealing and seed quantity.

7.3.2 Seed Legislation

The purpose of a seed law is to protect the farmer against purchase of poor quality seed. Seed quality is much more difficult to judge than the quality of other commodity. Progress requires safeguarding farmer interests and protecting seed producers and merchants from unfair competition. Seed legislation aims at promoting the overall development of agriculture, but it does not guarantee that quality seed reaches the farmer. Seed laws can only achieve their aim if high-quality seed is available. Seed laws must be enforceable and must fit the social, economic, and judicial make-up of the country.

There are two alternative systems of seed legislation. The first is the comprehensive regulator system, where in the law prohibits the sale of seed that does not meet a minimum standard of quality. In its extreme form the system requires a list of cultivars, and only certified seed of registered cultivars can be offered for sale. Seed producers and trader companies must be registered in order to do business. The second is the truth in labeling system, where in the seller must provide correct information about the seed to be sold. All seed is allowed to be marketed, but the quality is indicated on the label. In practice, each country's seed legislation has its own peculiar characteristics.

Control of imports is often included in seed legislation to protect the national seed industry and farmers, or for quarantine purposes. Imported seed must comply with the laws and regulations applied to home-produced seed. Quarantine restrictions may refer to seed-borne disease and insect and to weed seed. If improperly used, they can distort the international seed trade.

Chapter Eight

8. Seed Supply System

8.1 Introduction

Generation and transfer of improved technologies are critical prerequisites for agricultural development particularly for an agrarian based economy such as of Ethiopian. Despite the release of several technologies, particularly of improved crop varieties, there has been limited use of improved seeds by the majority of farmers (CSA, 2010). Among others, unavailability of quality seeds at the right place and time coupled with poor promotion system, is one of the key factors accounting for limited use of improved seeds, which further contributing for low agricultural productivity. Poor availability and promotion of improved seeds is due to inefficiency of the seed systems of the country.

8.2 Seed Systems in Ethiopia

Seed system in Ethiopia represents the entire complex organizational, institutional, and individual operations associated with the development, multiplication, processing, storage, distribution, and marketing of seed in the country. Smallholder Farmers are involved in multiple kinds of seed systems, which can guarantee them in obtaining the quantity and quality of seeds they need and to market their produce. 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. There is however, a fact that the formal system is the original source of improved seeds in 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.

8.2.1 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 like Pioneer. 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. However, are all largely involved in grain crops, cereals, pulses, oilseeds and forage crops seeds production. Thus, virtually none of these seed enterprises is involved in vegetable seed production locally or via imports, although vegetable seed production and importation is within their mandates and business objectives. In addition to the public seed enterprises, there are emerging small to medium domestic private seed companies/producers. Only a few of such small and medium seed producers are engaged in onion seed and potato seed tuber production and supply (**Table 6**).

Table 6. Small to medium seed companies engaged in vegetable seed production in Ethiopia, 2013

Seed companies/producers	Region	Zone, District	Seed produced
Bayihe Mekonnen seed producer enterprise	Amhara	West Gojjam, Bure	Chili Red pepper
Jama Integrated agricultural P.L.C	Amhara	West Gojjam, Mecha	Onion
Tesfaye Ararsa Potato Seed Producer	Oromia	West Shewa, Jeldu	Potato
Gizaw Tullu Vegtable Seed Production (AGMF)	Oromia	Southwest Shewa, Elu	Onion
Yohannes Girmay Farm	Tigray	Eastern Zone, Awilalo	Onion

Source: Amsalu *et.al.,* 2014

The formal seed supply system aims to supply adequate amounts of seed of high quality, at the right time and place, and at reasonable prices. The formal seed supply system is normally composed of seed multiplication, processing and quality control and marketing and distribution units. In Ethiopia, the only organization in the formal seed sector is the Ethiopian Seed Enterprise. The Ethiopian Seed Enterprise has only a limited capacity to produce the necessary quantity of seed to meet the national demand. The involvement of private investors in this system is, therefore, believed to be profitable and helpful as well to reduce the load on the Ethiopian Seed Enterprise and the scarce government resources.

Legal institutions such as variety release procedures, intellectual property rights, certification programs, seed standards, contract laws, and law enforcement are alsoan important component of the formal seed system of any country. They help determine the quantity, quality, and cost of seeds passing through the seed system.

8.2.2 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 60-70% of seed used by Ethiopiansmallholder 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 system due to the following key reasons;

- It is relatively cheaper and readily available in the framer'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.

Major limitations of the informal seed supply system are;

- Poor quality, lack of uniformity, distinctness, and stability.
- Physical mixture and pathological contamination.
- Irregular to use
- Market orientation is limited to the local areas only.

The quality of informal sector seed used by small-scale farmers can be improved in several ways:

- Train farmers in better selection, treatment, and storage of seed from their own farms.
- Encourage farmers to make their own selection of traditional varieties, to multiply and store seed of such varieties, and to sell this quality seed of traditional varieties to other farmers.
- Develop modern varieties at research stations, and produce good quality seed of these varieties through either formal or informal channels-whichever provides good (or acceptable) quality seed at affordable prices.

8.2.3 Integrated seed supply system

This method aims to improve the local supply system by burrowing technologies and improvements from the formal sector and using informal channels. There is a continuous process of exchange between the formal and informal systems, in information, in technology and, above all, in germplasm. Both formal and informal seed systems can play a complementary role. The formal system may serve in the production and distribution of improved seeds to the potential farmers while the informal one may serve resource-poor farmers with low income who cannot benefit from the formal system. Potential farmers themselves can also use the output of informal seed system when the formal system is not in a position to make improved seeds available in sufficient amounts.

8.3 Seed Law and Regulation in Ethiopia

The Seed Proclamation No.206/2000 has replaced a ministerial regulation No.16/1997, which was enacted to cover registration of varieties. Seed producers, processors, distributors, quality control, seed trade (import-export) etc. The seed proclamation No.206/2000 is more comprehensive and creates stronger legal frame work for the protection and control of the interest of all players in the seed industry. Moreover, field and seed standard prepared for 74 crops are officially issued for implementation.

The first National Seed Industry Policy was issued by the government in 1992, focusing on the following key areas:

- Plant genetic resources conservation and development
- Crop variety development, testing and release
- Seed production and supply
- Seed import and export and

- Reserve seed stock

8.4 Seed Regulatory Frameworks

Several proclamations were issued to legally enforce and implement various activities underlined in the national seed industry policy. They included the Plant Protection Decree (No. 56/1971), the Plant Quarantine Regulation (No. 4/1992), the Plant Breeders' Rights Proclamation (No. 481/2006), and the Access to Genetic Resources and Community Knowledge and Community Rights Proclamation (No. 482/2006).The most important of them all was the National Seed Proclamation No. 206/2000, which aimed at:

- Creating a legal framework for the protection of the interests, and control, of the users, originators, processors, wholesalers and retailers of plant seeds;
- Designating government agencies which support, advise and control individuals/organizations engaged in the production, processing, import, export, sale and distribution of quality seeds; and
- Promoting the use of quality seed through a smooth, effective and quick supply system.