UNIT 16 NEW TECHNOLOGIES

Structure

16.1 INTRODUCTION

In Unit 15, you have studied about the various issues pertaining to food security, ecological and genetic conservation and technology transfer. You know that we are faced with an increasing pressure on the existing land. We need to enhance agricultural productivity with the optimal use of resources that are facing the twin threats of depletion and degradation, particularly in the South Asian countries.

In such a scenario, our societies have to learn to take advantage of new technologies such as biotechnology, space information and communication technologies for improving the productivity of land as well as for profitable marketing of the produce. We also need to know about post harvest technology to prevent losses and encourage value addition to the produce. These new technologies are also eco-friendly and if adopted will be useful in ensuring healthy food and environment for our future generations. Therefore, we discuss these technologies in this unit. In the next unit, you will learn about agricultural waste management which is an equally important area for ensuring a better future.

Objectives

After studying this unit, you should be able to:

- discuss the applications of biotechnology, space, information and communication technologies in agriculture;
- describe the merits of post-harvest technology; and
- explain the measures required to use these technologies for attaining better environmental quality and improved productivity.

16.2 BIOTECHNOLOGY IN AGRICULTURE

Before we discuss the role of biotechnology in agriculture, you may like to know what biotechnology is and why it is important particularly if this is the first time you are studying about it. The word biotechnology is composed of the words BIO and TECHNOLOGY. Biotechnology is the application of biological organisms, systems or processes to manufacturing, agriculture and service industries. It is composed of a number of technologies based upon our increasing understanding of biology at the cellular and molecular levels. The techniques employed in biotechnology include simple processes like fermentation (used in the formation of curd, wine and vinegar), tissue culture or complex processes like cloning of DNA (including recombinant DNA manipulations), monoclonal antibody preparation, protoplast fusion, protein engineering, immobilized enzyme, cell catalyst, sensing with the aid of biological markers, etc. Biotechnology thus provides goods and services for human welfare by an integrated use of biochemistry, microbiology and engineering sciences, in order to achieve technological (industrial) application of the capabilities of micro organisms, cultured tissue cells and parts thereof [European Federation of Biotechnology]. Biotechnology may be defined as "the controlled use of biological agents, such as micro organisms or cellular components, for beneficial use".

Scope and Importance of Biotechnology

Biotechnology was being practiced long before the word was invented. The preparation of simple products like yogurt, cheese or wine is based on biotechnical methods, which are dated to prehistoric times. In the 20th century, Chaim Weizmann (in 1920s) produced butanol and acetone from starch by fermenting it with the microorganism *Clostridium acetobutylicum.* This was an important discovery because acetone was an essential component of explosives used during World War 1. This was followed by the discovery of penicillin by Alexander Fleming in 1929 from the cultures of the fungus *Pencillium notatum* and its subsequent commercial production.. This antibiotic saved millions of lives during World War II. Currently biotechnological programs are underway in many public and private-funded research and development organizations across the world.

Modern biotechnology involves reproductive technologies to influence reproduction in humans, plants, animals and gene technology, i.e., ways of manipulating genetic makeup of micro organisms, plants and animals to alter live stock and crops to suit our purpose, or to improve human health or in solving environmental problems. In this section we will explain briefly the various applications of biotechnology in food and agriculture, human uses and the environment.

16.2.1 Application of Biotechnology in Agriculture

Improvements in agricultural production and in food and nutrition depend on land, water and energy resources, which are finite in nature. Therefore, an important research and development goal of life sciences is to increase the biological productivity per unit area per unit of time. In this wide field, research also aims to increase food production with a higher nutrition value. The biotechnological applications in agriculture aim for improvements in potential crop yields, ratio of primary to secondary products, nutritive value of food and its physical properties (e.g., improved glutin content in wheat used for bread making). Resistance or capacity to tolerate abiotic and biotic stresses is another vital area of research. Similarly, biotechnology finds an important role in improving the quality of crops and livestock and their products. Let us now discuss some important areas of biotechnological interventions in agriculture.

- **Genetic enhancement of crops**

  Modern tools of biotechnology like tissue culture, recombinant DNA gene cloning, polymerase chain reaction, protein/metabolic engineering can revolutionize agriculture research by producing transgenic plants by modifying the genes through biotechnological methods. Modern biotechnologies can add greater precision and speed to plant breeding. Transgenics have been reported in 40 crop plants including maize, rice, soybean, cotton, rapeseed, potato, sugar beet, tomato and alfalfa but these are yet to be used commercially in the developing countries.

  Transgenic is an organism that has one or more genes that have been transferred to it from another organism.

  An enhanced production of cereal grains during the last forty-five years was primarily due to the availability of improved varieties of seeds developed by the application of classical genetics and plant breeding. The application of genetic engineering technology will henceforth allow plant breeders to access a much more diverse range of genes. The establishment of a plant breeding industry based on a deep understanding of cellular and molecular biology offers the possibility to overcome limits to production. For example, the pathway of photosynthesis in temperate plants involves fixation of carbon dioxide under the action of the enzyme ribulose-1, 5-diphosphate carboxylase. Further, small alterations in the characteristics of the enzyme via changes in the coding sequence of the appropriate gene/s may result in enhanced N-fixation efficiency in plants.

- **Improvement of quality and productivity in horticulture**

In-vitro studies play a major role in increasing productivity and quality of horticultural crops. The potential for growth in fruits, vegetables and floriculture seems unlimited in our tropical agro-climatic conditions. The private sector is introducing latest technologies including the development of controlled environment glass-house technology for operating climatic-controlled environments to produce, through tissue culture, large volumes of plants and flowers that would ensure their high quality for the export markets. It is here that biotechnology can step-in to enhance horticulture production: both quantitatively and qualitatively in a big way (see Box 16.1).

Box 16.1: Tissue culture

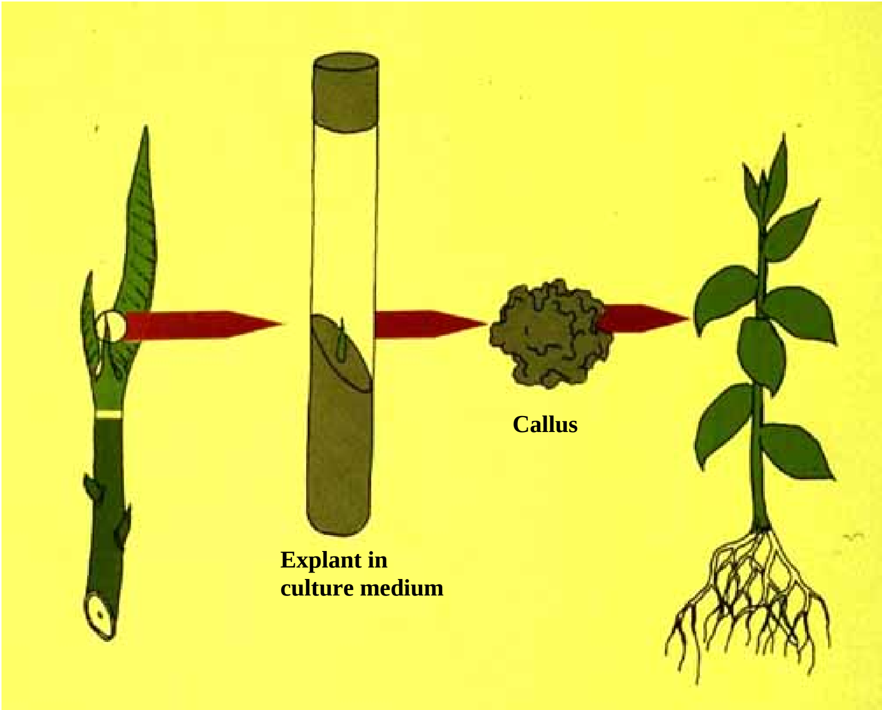

Fig.16.1: Propagation of plants through tissue culture

Plant cells can be cultured on agar plates containing the necessary nutrients. The advantage is that many individual plants can be produced quickly in comparison to the conventional method of plant propagation. Also, many clones can be kept alive in this way in a small space. The formulation of the growth medium is changed depending upon whether we are trying to get the plant to produce undifferentiated callus tissue, multiply the number of plantlets, grow roots, or multiply embryos for "artificial seed". The main advantages of tissue culture are:

- ♦ New crop plant clones can be propagated quickly.
- ♦ Some ornamental plants that may be slow-growing or hard to propagate can be produced.
- ♦ Callus cells are convenient for gene transfer through experiments.
- ♦ Transgenic plants can be kept safe during tissue culture and propagated easily.

- **Specific pathogen-free plant production**

  Virus is a protein. Viruses harbour in many horticulturally important crops and have the potential to produce disastrous consequences. Fortunately, viruses and other pathogens, in most cases, are unable to invade the plant meristem.

  Meristem is an embryonic plant tissue that produces new cells through repeated mitotic divisions.

  Meristem cultures have been successfully used in carnation, chrysanthemum, papaya and banana. These genetically modified (GM) plants hold a tremendous promise for small farmers. The biotechnological techniques when coupled with application of different temperatures and chemicals (thermo and chemotherapy) as has been done with potato demonstrate greater efficiency. Cardamom clones have already gone into brisk business since then and other devastating diseases have attracted the attention of planters.

- **Nitrogen fixation**

  Another potentially significant area of bio-technical research and development is that of the introduction of symbiotic nitrogen fixation into non-leguminous plants. Novel symbiotic vectors like gall forming *Agrobacterium tumefaciens* and root nodule bacteria (*Rhizobium* spp.) have delivered genes to leguminous plants. Transfer of foreign genes to host cells has been achieved. However, the *Rhizobium* does not transfer DNA to the host itself but functions as a chemical factory converting raw materials into useful products that are passed on to the host plants. In addition, a segment of DNA has also been identified that permits high-level synthesis of foreign genes in root nodule bacterioids. These foreign genes are expected to enhance the efficiency of nitrogen fixation and delivery of plant growth regulators and perhaps very soon, increase even pest resistance.

- **Increased disease resistance**

  In vitro tissue culture and selection by bio-technical tools has been used to develop pest resistance and resistance to herbicide, e.g., maize plants have been developed which resist herbicide toxicity. This is an example of transgenic maize. It is currently grown on an extensive scale in U.S.A.

- **Improved quality of plant products**

  Plant varieties have been developed whose seed proteins have been biogenetically modified to suit our needs. An example is the improvement in bread making quality of high yielding, home grown wheat. GM crops also improve the nutritive value of the cereal proteins for humans and also for pigs and poultry.

- **Improving resistance of plants to stress**

  The potential for improved GM crop productivity arising from the presence of mycorrhizal fungi, which facilitate water and nutrient uptake, particularly phosphorus has been demonstrated. Such plants show increased resistance to abiotic stresses. Similarly transgenic plants have been grown in poor soils, using saline water which prevails in coastal lands to yield non-traditional foods and fuels.

- **Biotechnology and forestry**

  Unlike annual crops, the breeding behaviour of trees is complex and their life cycle is long. Therefore, one has to wait for many years to produce tree varieties with desirable traits. The modern non-conventional methods of genetic engineering, tissue culture and somatic hybridisation have infused new hope for enhancing forest quality and productivity with quick results. These non-conventional methods of tree production are expensive, but when combined with conventional and new bio technological methods, costs become reasonable. For improvement in forest trees, where conventional methods of selection, breeding and progeny testing are difficult, tissue culture techniques could definitely reduce the time for selection and propagation of desirable traits.

- **Biotechnology and livestock production**

  Improvements in the efficiency of reproduction in farm livestock involving bio-techniques such as super ovulation, embryo transfer and cloning are already having an impact in livestock breeding. One of the best examples of biotechnology and livestock production relates to increased milk production from dairy cows. Daily administration of growth hormones to young stock has been shown to increase live weight and feed conversion in cattle, sheep and pigs; the increased gain seems to be associated with a higher content of protein at the expense of fat.

16.2.2 Other Uses of Biotechnology

Biotechnology is being applied in industry, in human uses including development of medicines, genetic testing, DNA profiling and cloning as well as to assist work on overcoming environmental issues.

- **Biotechnology and industries**

  When biotechnology is applied at industrial level, it is called bio-industry. It includes on the one hand, industrial activities where biotechnologists can replace currently in-use technologies and on the other hand industrial activities where bio techniques play an important role. There are several areas in which such technologies are being used in the chemical, food, agro-based and pharmaceutical industries.

  Enzymes are biological catalysts and have been used for many years as isolating agents particularly in food industry, e.g., rennin, papain and invertase. These enzymes have been used in wheat and barley brewing, baking and biscuit making, and in textiles industry. Some plant enzymes generate chemicals, which provide crops with a certain amount of resistance to insects and pests. The examples are saponins, phenolics, cardenolides and alkaloids. GM cotton is currently being test grown in several parts of India to evaluate its efficiency against insect pests.

- **Biotechnology and human and animal health**

  Immunological studies include defence against infection, prevention of disease by immunization, blood banking, hypersensitivity and autoimmunity. Bio techniques are used to measure immune responses for diagnosis and progress of certain diseases and manufacture of hormones and drugs, which are related to human health.

  Several vaccines have been developed by the application of recombinant DNA technology for prevention of disease in humans, piglets and calves.

  Biotechnology and medicines: The contribution of biotechnology to the practice of medicine through the discovery and development of a number of potent antibacterial antibiotics is widely recognized. A major ongoing effort is concerned with the discovery of new structures with antibacterial activities and the chemical modification of existing natural products. Although these antibiotics have found widespread use as growth promoters in the area of animal health, only more recently have microbial products been produced primarily for animal growth or agricultural purposes. As an example, monensin is a growth permittant for ruminant animals. Bacteria, fungi and viruses have been most commonly researched as potential microbial biocides. The development of low cost production methods and successful formulation of products such as microbial insecticides represents a commercial cutting edge for biotechnology in the years ahead.

Biotechnology is the *third* wave in the development of biological sciences and represents an interface of basic and applied sciences, where gradual and subtle transformation of science and technology is being witnessed. Although in agricultural science and development the future clearly belongs to biotechnology, concerns regarding GM technology and release of genetically modified organisms (GMO) into the environment ranging from its potential impact on human health and the environment have been voiced in various fora. There are economic concerns as well. It is essential that all these issues are resolved if we are to reap the potential benefits of this new technology.

SAQ 1

a) List at least five aspects of agriculture and food production where gene technology may be used.

b) The use of biotechnology has the potential for both positive and negative impacts on the environment. Discuss an example of both positive and negative impact that you may have come across recently.

(**Hint:** You could look up some magazines or newspaper cuttings on biotech usage regarding GM tools.)

16.3 SPACE, INFORMATION AND COMMUNICATION TECHNOLOGIES IN AGRICULTURE

In the past few decades, we have witnessed rapid developments in the space, communication and information technologies (ICTs). Today we have at our disposal an extensive network of telephones, radio, TV, computers, INTERNET and satellites to help us reach the remotest corner of the earth (Fig. 16.2).

Fig. 16.2: ICTs in use today

These technologies offer uncommon opportunities to our agricultural research, development and farming institutions for **weather-proofing** our farming, sustaining its productivity and providing in-time advice on **markets** and on yield-reducing biotic and abiotic stresses. ICT tools are convergent and therefore these can effectively solve the complex challenges posed by technological, ecological, economic and equity issues on an integrative platform. Further, with the increased availability of ever-faster computers, the application of IT tools can speedily answer many intricate questions on:

- the rational use of non-renewable natural resources,
- maintenance of the quality of our environment,
- the magnitude of the impacts of various options of farming on the land quality, its degradation (and desertification) and
- the carrying capacity of land for human, cattle and diverse biotic populations.

Thus the use of IT, communication, and space technical tools can speed up the pace of the processes of development to meet the needs of our farm families both during production and post-production phases of their farming. Let us learn about the role of space, communication and information technologies in agricultural R&D and transfer of new methods of farming.

There are three broad ways by which space, communication and information technology tools can benefit our farming communities.

- **Collection of data and information processing**

Space technologies (in particular, the remote sensing satellites installed in space) provide a unique set of data of the land cover and its natural resources through various sensors placed in the satellites. There are a number of satellites girdling the globe. They are observing the weather and natural resources and are sending digital data on a regular interval. These satellites are equipped with multispectral and multi-temporal space-borne sensors. The data received can be processed to give information on vegetal cover, its quality and extent of changes that have occurred over-time.

For example, the UNEP, FAO and UNDP recently completed a pioneering study on the **quality of the land resources of South Asia**. It is estimated that 40% of the region's agricultural land (140 million ha) has suffered from one form of land degradation or the other. The intensive food production areas here have been largely eroded of their floral and faunal diversity, the ground water aquifers have been seriously reduced, forest resources have dwindled (to much less than the required 33% of the geographical space), multiple deficiencies of plant nutrients are a common occurrence, and biotic stresses are on the increase.

A Geographic Information System (GIS) is a collection of geographical referenced data, personnel and computational tools designed to efficiently provide information for large tracts of land. GIS technology integrates common database operations, such as, query and statistical analysis with the unique visualization and geographic analysis benefits offered by the maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, planning strategies and in decision making.

Space, communication and information technological tools can help reconstruct and restore these degraded agro-ecologies, maintain their vigour in good health so that evergreen revolution is sustained to feed our increasing population.

The space observed data when analysed together with other (geologic, edaphic, hydrologic, weather and socio-economic) in a geographical information systems (GIS) environment, can provide a firm basis to land use planners to devise alternate options for sustaining productivity of

a) different farming systems and their impacts on ecological, natural and environmental resources, and

b) on their economic implications together with the costs of reversing any losses to productivity due to land degradation.

- **Sharing of data and information**

Space, communication and ITs have almost revolutionized the systems of data collection, its warehousing and transfer from one site to another. Through the INTERNET, data can now be shared nationally and internationally, almost in real time. Thus interpretation of data into useful information by inter-and cross disciplinary teams of science and development workers can be made at a rather fast pace. The ecologies threatened with temporary or permanent lowering of productive capacity of land can now be easily delineated and mapped, and action programs initiated to stall the damage and repair it in the shortest period of time.

- **Adoption of precision farming**

  Space, communication and IT enabled services can be of great assistance to our farming communities for progressively adopting precision farming. This is a management strategy that employs detailed site specific information to precisely manage production inputs. The application of precision farming techniques can improve the productivity of our agriculture and its economic and environmental sustainability. The chemical pollution can also be minimized by the adoption of precision agriculture methods as it uses integrated pest, nutrient and crop management.

  Thus, we are entering the knowledge-based century dominated by an increased use of space and information technologies which will reduce the developmental gap and increase access to innovative farming systems options. However, the benefits of digital technologies can only be reaped if our research and development systems create a strong compelling environment and vision which should include, a) honesty, generosity, respect for evidence, and openness to all ideas and opinions irrespective of their source; b) knowledge sharing and capacity building, c) building networks of trust by connecting scientists to each other and to their local farming communities; and d) providing impartial scientific advice.

  There is thus a challenge here for the South Asian agricultural research and development institutions to revamp their R and D framework for embedding knowledge based space, communication and information technologies for upgrading farm output both during its production and post-production phases. Time is not on our side. In this endeavour, the earlier we pick up the gauntlet, the better it would be. Agriculture [and food processing] and information technology are important areas where some countries in the SAARC region have a core competence for integrated action to remove poverty and usher in sustainable rural livelihoods. Let us assess where we stand today and see what can be done to meet these goals. At this point, you may like to assess yourself.

SAQ 2

What elements of space, information and communication technologies are useful for agricultural development? List the applications of these technologies in agriculture.

We now analyse the progress made so far in these areas and suggest measures that could be taken in the near future.

Progress made and some suggested initiatives

- In some SAARC countries like India, agricultural research and development agencies have invested large resources in establishing electronic communication network facilities; the staff have been trained, and computer software are in day-to-day operational use. It is time that the available data sets are computerized, geo-referenced and cleaned. The data should be placed in a common format, so that it is easily accessible. Further, all new research and development data collected from now-on should be formatted to under grid the decision support system for agro technology development and transfer. Comprehensive minimum data sets on crop (commodity), management, location, weather and geo-coordinates should be collected on a unified basis, digitised and made available on the internet to all interested parties. This one step would give a boost to our research productivity and its quality.

- Agricultural research and development agencies of countries in the South Asian region should adopt knowledge-based rural development villages (at least two in each of the agro-ecological zones) patterned after the very successful information village research project launched in the union territory of Pondicherry in India by the M.S. Swaminathan Research Foundation (MSSRF). Empowerment of farming communities with information and communication technologies has been shown to play a major role in environmentally sustainable rural development. MSSRF believes that such an effort allows not only reaching the poor but also helps them to achieve food security and social justice. A multi-year program of work should be undertaken so that the entire region is covered by the year 2025.

M. S. Swaminathan Research Foundation (MSSRF) registered in 1988 in India is a non-profit Trust, with the mandate to impart a pro-nature, pro-poor and pro-women orientation to a job-led economic growth strategy in rural areas through harnessing science and technology for environmentally sustainable and socially equitable development.

- Agricultural research and development organizations of various countries should join hands in actively promoting the use of new information and communication technologies. Regional networking to achieve integrated sustainable development should be encouraged. In this connection, advantage could be taken of the experience of the Integrated Mission for Sustainable Development (IMSD) launched by the Department of Space, India through inter-governmental efforts. The objectives of IMSD are to generate plans at 1:50,000 scale for land and water resources development for use by district-level natural resources managers.

  Spatial databases on natural resource themes (in GIS environment) including land use, soil, slope, hydro-morphology, groundwater prospects, rainfall and climate, drainage watershed and surface water bodies, road network and settlement locations and village boundaries have been generated using satellite remote sensing data and conventional information for some selected districts. GIS technology is used to integrate and analyse resource themes for arriving at plans for land and water development, alternative land uses based on resource potential, optimal use of ground water and soil conservation. Agricultural research and development agencies could provide the required interface between the farmers, stake-holders at the watershed or community level in the development of action plans. Such activities could be undertaken in all developing countries of the SAARC region.

- The Department of Space in India has three other programs: these are CAPE (Crop Acreage and Production Estimates) and FASAL (Forecasting Agricultural Output using Space, Agro-meteorology and Land based observations) in which ICAR (Indian Council of Agricultural Research) and similar agencies from other countries should be encouraged to take a deep interest. Some agricultural research and development workers may be placed with the CAPE and FASAL groups to provide the required linkages between the agricultural R and D and space agencies. ISRO (Indian Space Research Organisation) and ICAR are already working together in an experiment called Agricultural Resource Inventory and Survey Experiment (ARISE). The scope of these works may be enlarged into well-focussed programs to cover all the agro-ecologies in the South Asian region in a time-framed fashion so that the entire region is covered within a given time frame, say, by 2025.

- To quote Professor M.S. Swaminathan, an eminent agricultural scientist from India, modern ecological agriculture offers great opportunities. We have a very large untapped yield reservoir in our country (true for all South Asian countries). We can take advantage of the tools provided by the space, communication and information technologies to usher in an era of intensified, diversified and value added farming. All the technical bits and pieces are available on the shelf; we need to put them together. We can make the unique experiments universal by putting the space, communication and information tools and precision agricultural technologies together on an operational basis. The state of Andhra Pradesh in India has already launched its first 'cyber Grameen' to harness the power of internet broad band for providing one-stop destination e-services including the development of agriculture and horticulture. We should get our priorities right and get moving to usher an era of greener future.

The discussion on space and ICTs should have given you enough food for thought and underscored the need for urgent concerted action. As an exercise, you may like to determine what kinds of voluntary or governmental initiative exist in your region/country. Attempt the following SAQ and then you may move on to the study of post-harvest technology.

SAQ 3

What programmes, if any, have been undertaken by NGOs or government departments in your region/country for sustaining greener agriculture?

16.4 POST-HARVEST TECHNOLOGY

We begin with the example of India to underscore the importance of post-harvest technology. In India, some 60 million tons of food grains are held as 'buffer' stocks. This very large quantity of food needs to be sustained as wholesome edible commodity suitable for human consumption under varied agro-environments across the country. Any loss in weight or deterioration in quality due to infestation with insects, fungi or other grain pests or due to wetting of the grain can end in serious economic loss. Many a times the food becomes unsuitable for consumption.

In the case of fruits and vegetables or fish products which are highly sensitive to post-harvest handling, the deterioration in quality occurs rapidly if such foods are not properly handled. Because of their high moisture content, which typically ranges between 70% to 95% and soft texture, the losses are usually caused by rotting (due to bacteria, fungi). The shelf life of these perishable agricultural foods is fairly short compared with cereal, pulses and oilseeds. Thus, steps need to be taken to prevent this loss. Post harvest technology helps us meet this goal.

It is estimated that about 10 % of the yield loss occurs during harvest and field drying of crops, and a somewhat similar loss is sustained during field processing (primarily threshing), transport and storage of food-grain and oilseed crops. The weight and quality losses in the case of fruits and vegetables are much higher. About 10-20% of the horticultural crops and vegetables perish due to poor methods of harvest and on-farm processing. Lack of appropriate packaging and transport facilities particularly available with the small holders add to loss of quality and food value.

The monetary post-harvest losses are estimated at Rs. 20-30 crores annually for India. However, a more important point for the countries in this region is that we are all food-deficit nations. Food that deteriorates due to wrong post-harvest handling is food wasted. Thus, steps need to be taken to prevent this loss. Post-harvest technology helps us meet this goal.

Let us understand what post-harvest technology is.

16.4.1 What is Post Harvest Technology?

In its broadest sense, the term **post-harvest technology means the conservation, protection (of quality), processing, transport, packaging, distribution, marketing and utilisation of the agricultural products upon their harvest or at the moment of separation of the edible commodity from the plant** (as in the case of agricultural crops and fruits including vegetables) **or from water** (as in the case of fish and aquatic edible species) **or products obtained from the animals** (e.g., meat, eggs, poultry, milk etc.). In this section we will mainly focus our discussion on post-harvest technology as it relates to agricultural crops.

Role of post-harvest technology

The post-harvest technology is a highly diverse and inter-disciplinary subject of study. It includes

- selection and planting of appropriate varieties of crops, vegetables and fruits suited to the agro-environment and their end-use;
- the method/s of harvesting and field transportation to on-farm handling and storage;
- processing of the harvested food, vegetables, or fruits on the venue of production; and
- methods of packing, mode of transport from the farm to the various points of the marketing-chain and processing prior to sale.

The post-harvest technology of agricultural crops is important for the food security, on the one hand, and has economic dimensions on the other.

The application of the tenets and the adoption of post-harvest technical practices could potentially prevent,

- losses of weight of food, fruits and vegetables during their harvest and in the course of transportation of these products to storage, sale and consumption points;
- loss of quality by conserving their appearance and nutritional value; and
- any reduction in value addition.

Thus, on both these counts – economic and nutritional, the preservation of food, its acceptability and access is basic for food and nutritional security. So there is a strong justification for the large-scale adoption of post-harvest technologies and due attention must be given both to their scientific and technical aspects. To be effective, the post-harvest technological measures will have to be adopted by the growers of food – the farmers and farm cooperatives, marketing institutions at the various levels, wholesalers and the retailers. For this, we need to understand what kinds of losses take place at the post-harvest stages. But before moving on, you may like to consolidate these ideas.

SAQ 4

a) What do you understand by post-harvest technology?

b) Explain in the context of your own region/country, why post-harvest technology needs to be adopted.

16.4.2 Post Harvest Losses and their Prevention

Both quantitative and qualitative losses of agricultural produce occur at various stages of their post-production, i.e. at post-ripening stage. These losses, as explained earlier, refer to loss of weight, diminished food value, loss of quality and non-acceptance of the food by the consumer. These, thus result in its decreased price leading to economic losses. A case in point is the recent rejection of wheat produced in India by Iraq and Afghanistan. Our wheat has been purported to be contaminated with Karnal bunt (a fungus).

Weight-loss usually occurs due to wrong timing or methods of harvest of crops or both. Sometimes crops are left in the field, after full ripening. In the field, the produce may be infested with insect/pests or if the humidity is high it can become mouldy, or the grains may even germinate, if the seeds have no dormancy.

In the following two sections post-harvest losses of food crops (e.g., cereals, pulses, oilseeds) and of the perishable crops (e.g., vegetables, fruits etc.) are discussed in some detail.

Cereals, pulses and oilseeds

These food crops are characterised by low (10-20%) moisture content at the time of their harvest, small unit size (seed weight is typically less than 1g), very low respiration rate having a very small generation of heat during storage. Heat production is typically 0.05 mega joule/ton/day for air-dry grains. These crops are generally hard textured and have a stable shelf-life; if stored in dry, well ventilated storage, these crops can maintain their quality for several years. However, in most SAARC countries, majority of the food grains are produced by small farmers having limited means. In order to help you appreciate and understand the post-harvest losses that can potentially occur in food grain crops, we discuss here the prime example of rice crop in some detail. Rice is a major food crop and is grown in most countries.

The various kinds of estimated losses in post-harvest of rice are summarised in Table 16.1 given below.

Table 16.1: Estimated post-harvest losses of rice in South and South-east Asia

Post-harvest Operation	Range of losses
Harvesting	1-3%
Threshing	2-6%
Drying	1-5%
Handling	2-7%
Milling	2-10%
Storage & Transportation	2-6%
Total	**10-37%**

Source: P.H. Pandey, Principles and practices of post-harvest technology (Kalyani publishers. First Edition. Reprint 2001, 453pp).

You can see from the table given above, that the post-harvest losses for rice crop are at best estimated at 10% and at worst these can be as high as 37% or about one-thirds of the crop produced. Through the use of appropriate post-harvest technologies, these losses can be substantially reduced. In Japan and in the United States of America where rice production is highly mechanized, the post-harvest losses in rice hardly exceed 2-3%. Even in Thailand these are estimated at less than 5%.

The question is, therefore, how to prevent such losses.

Prevention of losses in cereals, pulses and oilseeds

We outline some measures that can be taken to prevent post-harvest losses.

- The first step in the post-harvest technology is the harvest of the crop at appropriate seed moisture. In rice, it has been found that the crop should be harvested when the seed moisture is at 20-22%. Traditionally, farmers harvest paddy at about 16% moisture content and then sun-dry it in the field. This practice results in drying of the seeds during the day, and their wetting during the night, when the relative humidity is high. Thus a dry-wet cycle of grains called 'sun-checks' sets-in which results in grain cracks during milling of rice. The percentage of broken rice grains is therefore much higher. The quality of rice thus seriously suffers. Such rice attracts a much lower price in the market.

  Researchers have now recommended an improved method of post-harvest technology for rice. It is suggested that the rice crop should be harvested when the moisture content of the paddy is 22 ± 2%, and it should be gradually dried to a moisture content of about 12%. The paddy thus should be dried on a dry, preferably cemented floor which is covered. The produce should be raked frequently.

  Generally small farmers do not have the necessary facilities. They are advised to join farmers-cooperatives or sell their produce to rice millers, who generally have adequate infrastructure for efficient handling of paddy. This simple operation of the new post-harvest technology of rice has been shown to increase the yield of paddy by 10-20%.

- The second step in the production of rice involves its storage prior to parboiling and milling. Field drying of paddy, particularly in the farmers' traditional method in Southern Indian states, exposes the crop to high temperatures. When paddy is rapidly dried, the loss of a vital vitamin called thiamine usually occurs. This reduces the nutritional quality of the rice. Also, if paddy is not stored in dry, well-aired storage bins or go downs, it may be infested with insect/pests, where it is estimated to suffer a potential loss of about 12% of available protein in the grains.

- The third step in the production of rice involves its de-husking and polishing. Currently modern methods of paddy milling are available which cause minimum damage to the outer-seed coat thus retaining essential minerals and vitamins. In many ways the farmers' traditional method of de-husking of paddy is superior to the modern methods of factory-based milling and polishing the rice as it preserves the essential vitamins and minerals in the seeds. However, such rice is not pearly white and it does not attract a better price.

- The final steps in post-harvest of rice are its packaging, storage, transport and marketing.

The post-harvest losses of grain crops like wheat, sorghum millets and other small grain crops also range between 10-40%. All these crops suffer from extensive grain quality deterioration if these are exposed to high moisture at the time of their harvest or during storage. The seeds of these crops are prone to the attack of moulds, which makes them unsuitable for consumption by humans or animals or poultry. The loss of protein in pulses during post-harvest stage is particularly serious. It has been estimated that the cowpea and bean crops stored in bins under farmers traditional systems, can suffer a potential loss of protein of up to 81%, in a year's time. This is an avoidable food-quality loss.

We now give an exercise to help you fix these ideas.

SAQ 5

a) Taking rice as an example crop, estimate the losses due to its various post-harvest operations and show them in a table.

b) At what moisture content should paddy be harvested and how should it be dried to reduce shedding, shattering and losses due to broken rice?

Prevention of losses in perishable crop

The perishable crops are grouped as crops which have a typical moisture content of 70-95%. Vegetables and fresh fruits are examples of perishable crops. These crops have a low level of natural protection against weather, pests, bio-chemical deterioration and transportation. These conditions are aggravated in the tropical climatic regions where required storage and suitable transport conditions are generally lacking. The shelf life of the perishable crops ranges between a few days to a few weeks. The causes of spoilage, the rate at which it occurs, the degree of loss in weight and quality, are substantially different in perishable agricultural produce. Because of these vital differences, it is necessary to identify the causes of loss in each case and design appropriate set of interventions to check post-harvest losses in perishable crops.

Causes of loss of perishable agricultural produce

- **Primary**: These are those causes that directly affect the food and its quality. These may be

  a) **Microbiological**, where damage is generally caused by infection of the produce with fungi and bacteria. These micro-organisms consume only small amount of food or colonize the outer coat of the vegetables and fruits, but they damage the produce to a point that it becomes unacceptable for consumption. The moulds produce mycotoxins which are often poisons. The best known example of mycotoxins is *aflotoxin*, which is produced by the mould *Aspergillus flavus*. It is a liver carcinogen. It is commonly found in groundnuts. Another mycotoxin which is found in apples and pear products is *patulin*. It is caused by *Penicillium expansum* and infects fresh fruit.

  b) **Chemical**, which cause loss of colour, flavour texture and nutritional value of the agriculture produce. For example, Maillard reaction in fruits and vegetables, causes browning and discolouration. Some pesticides and harmful chemicals which are not biodegradable also persist in fruits and vegetables (e.g., DDT can persist for a long time and is carcinogenic);

  c) **Biochemical** which are enzyme activated reactions that mainly occur during storage. These give rise to off-flavours, discolouration and softening of fruits and vegetables. The biochemical and microbiological reactions can be slowed down considerably by freezing or refrigerating the fruits and vegetables; and

  d) **Biological** (e.g., rodents, birds, large animals), **mechanical** (e.g., bruising of produce during handling and transportation), **physical** (e.g., excessive heat or cold) or **chemical** (premature ripening of fruits by chemicals e.g., ethylene).

- **Secondary**: These causes of post-harvest loss of perishable agricultural commodities are mainly *inadequate harvesting, packaging and handling skills; lack of appropriate containers for handling of perishables; inadequate storage facilities to protect the deterioration of food; long time-lags between harvest and marketing; inadequate refrigerated storage capacity; lack of appropriate drying facilities* and finally *lack of marketing infrastructure*. The various stages at which secondary post-harvest losses of perishable agricultural commodities occur are:

harvest, preparation, preservation, processing, storage, transportation, and *marketing*.

Controlling post-harvest losses of perishable commodities

Few accurate and reliable data are available on the magnitude of post-harvest losses of fruits and vegetables. As a general guide, the FAO believes that 25-35% of production losses occur in the case of fruits and about 40% losses take place in vegetable production in South and South-east Asia. These losses can be controlled or reduced by:

- Harmonizing the harvesting techniques with the kind and type of fruit and vegetables.
- Careful handling and storage of the produce.
- Use of minimal cost cooling techniques; where appropriate, use of evaporative cooling. Crops should be harvested early in the morning and stored in well ventilated spaces. These should be cooled promptly after harvest.
- The produce should be stored at optimum storage temperature. For most tropical horticultural crops it is between 7° and 10°C.
- Storage of vegetables in an appropriate humidity environment (if not refrigerated) in order to maintain the product in a better condition.
- Maintenance of high-class sanitation in all storage areas.
- Use of growth retardant sprays. A number of specific growth retardant sprays are available. These may be used, in consultation with experts.

Post-harvest handling of agricultural produce is an important area of agricultural research and development. Adoption of ‘good practices’ of post-harvest technology could result in substantial savings of agricultural produce from deterioration and waste; it would thus add to the ‘food security’ of the country. Post-harvest technology also preserves and enhances the quality of the food; it would thus provide ‘nutritional security’. The progressive implementation of post-harvest technological programmes is economically viable, environment-friendly, and highly needed for sustaining a greener future for the country.

In terms of R and D in India, at the national level, Central Institute of Post-Harvest Engineering and Technology (CIPHET) is the nodal organisation. It is leading research and development in agricultural production catchments on agro-processing industries. It is equipped with pilot plants, industrial liaison, and technology transfer facilities. It has a department of international cooperation. CIPHET was established first in Ludhiana (at the campus of the Punjab Agriculture University) in 1989 and has a campus at Abohar in Punjab (established in 1993). An All India Co-ordinated Research Project on Post-Harvest Technology (established in 1972) is operational in 18 centres across the country. It coordinates research and development efforts on post-harvest technology in the various eco-regions.

In sum, most farmers in the SAARC countries currently sell their farm production without any grading or processing. If they carry out primary processing at the village level, it will generate value addition to the food produce, conserve and enhance food quality, and will thus generate additional income and employment in the rural sector.

With this we would like to end the unit and summarise its contents.

16.5 SUMMARY

- Three new cutting edge technologies which can facilitate leading our agriculture towards a greener future are: **Biotechnology**; **Space, information and communication technologies**; and **Post harvest technologies** to preserve the food and its quality while avoiding losses.

- **Biotechnology** is the new cutting-edge arm of life sciences which applies biological organisms, tissue culture techniques, cloning of DNA, including its recombinant manipulations, monocolononal antibodies, protein engineering, protoplast fusion, immobolized enzyme, cell catalysis, sensing with the aid of biological markers. It aims to provide goods and services for human welfare by an integrated use of biochemical, microbiological, and engineering sciences, which impact almost all aspects of living organisms including crop plants. In agriculture, the major use of biotechnological tools is to produce genetically engineered transgenic crop plants, which are hoped to perform better in stressed environments. Such plants can ward-off insect/pest attacks, give better and quality produce which have a higher nutritional value and shelf-life.

- The use of the products of **space, information and communication technologies** has already revolutionized the use of visual and voice media. Today, we can receive TV signals in the most remote places and talk to any one across the world by pressing a few buttons on a cellular phone system. Thus a farmer or farmer's cooperative situated in any remote corner of the country can be in touch, on a real time basis, with the markets, on the one hand, and with the technical advisory services, on the other.

- Space, information and communication technologies have **several applications in agriculture**. Remote sensors in satellites generate data which when read in conjunction with geologic, weather and socio-economic data in a geographical information system (GIS) environment, can provide a firm basis to land use planners to devise alternate options for sustaining productivity of various land uses and their impacts on ecological, natural and environmental resources together with their economic implications. Farming communities empowered with information and communication technologies can weatherproof their production and gain access to useful information as well as markets for selling their produce profitably. The Department of Space in India has also undertaken several missions for sustainable development using space, communication, and information technologies aimed at a greener future of our agriculture and to achieve food security and social justice.

- The third set of new technologies for ensuring a greener future for our agriculture is related to **post-harvest technology**. It aims at saving food losses that take place during the harvesting of crops – both agricultural and horticultural, and during processing until these reach the ultimate consumer. The kinds and extent of harvest and post-harvest losses of cereals, pulses and oilseeds (agricultural crops) on the one hand and of perishables (fruits and vegetables) on the other have been described. The post-harvest losses in the case of agricultural crops are estimated to range between 10 and 40%, while in the case of perishable these could be as high as 60% or even a total loss of the crop.

- The **losses of quality** due to in-appropriate post-harvest handling are identified. In the case of rice, losses of protein, vitamins and minerals occur due to wrong milling techniques. If the drying cycle of paddy is not well managed, the content of the broken rice has been shown to increase considerably, which results in economic losses. Similarly losses in the protein content in pulses can be considerable, if these crops are not properly stored. A number of steps for controlling post-harvest losses of agricultural crops have been suggested. Food saved is the food available for ensuring food and nutritional security of our people. Also, the quality of food has assumed a special importance in view of the

globalisation of agriculture in the post-WTO regime. Post-harvest technology saves both quantity and quality of food.

16.6 TERMINAL QUESTIONS

1. Discuss the scope and limitations of biotechnology in sustaining agricultural production.
2. What are GM crops? How are they useful in avoidance of biotic and abiotic stresses in crop plants?
3. Discuss how modern communication technologies can improve extension of new technologies on real-time basis in agriculture improving the farmer's economic situation.
4. How do post-harvest technologies differ for storage of food grains and fruits and vegetables?
5. How do perishable crops differ from the food grains in terms of post-harvest losses? What are the essential elements of the post-harvest technology for fruits and vegetables to minimise losses?

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