**History and role of plant breeding in society**

**What is plant breeding?**

Plant breeding is a deliberate effort by humans to nudge nature, with respect to the heredity of plants, to an advantage. The changes made in plants are permanent and heritable. The professionals who conduct this task are called **plant breeders**. Consequently, the term “plant breeding” is often used synonymously with “plant improvement” in modern society. It needs to be emphasized that the goals of plant breeding are focused and purposeful.

It should be mentioned at the onset that it is not every plant character or trait that is amenable to manipulation by breeders. However, as technology advances, plant breeders are increasingly able to accomplish astonishing plant manipulations, needless to say not without controversy, as is the case involving the development and application of **biotechnology** to plant genetic manipulation. One of the most controversial of these modern technologies is **transgenesis**, the technology by which gene transfer is made across natural biological barriers.

**Thus plant breeding may be defined as:** the art, science and technology of improving genetic make up of crop plants in relation to their economic use for mankind.

Plant breeders specialize in breeding different groups of plants. Some focus on field crops (e.g., soybean, cotton), horticultural crops (e.g., vegetables), ornamentals, fruit trees (e.g., citrus, apple), forage crops (e.g., alfalfa, grasses), or turf species. More importantly, breeders tend to focus on specific species in these groups. This way, they develop the expertise that enables them to be most effective in improving the species of their choice. The principles and concepts discussed in this book are generally applicable to breeding all species. However, most of the examples supplied are from breeding field crops.

**Goals of plant breeding**

Before initiating a breeding project, clear breeding objectives are defined based on factors such as producer needs, consumer preferences and needs, and environmental impact. Breeders aim to make the crop producer’s job easier and more effective in various ways. They may modify plant structure so it can resist lodging and thereby facilitate mechanical harvesting. They may develop plants that resist pests so the farmer does not have to apply pesticides or can apply smaller amounts of these chemicals. Breeders may also develop high-yielding varieties (or **cultivars**) so the farmer can produce more for the market to meet consumer demands while improving his or her income. The term cultivar is reserved for variants deliberately created by plant breeders. When breeders think of consumers, they may, for example, develop foods with higher nutritional value and that are more flavorful. Higher nutritional value means reduced illnesses in society caused by the consumption of nutrient-deficient foods, as obtains in many developing regions where staple foods often lack certain essential amino acids or nutrients.

Plant breeders may also target traits of industrial value. For example, fiber characteristics (e.g., strength) of fiber crops such as cotton can be improved, while oil crops can be improved to yield high amounts of specific fatty acids (e.g., the high oleic content of sunflower seed). The latest advances in technology, specifically genetic engineering technologies, are being applied to enable plants to be used as bioreactors to produce certain pharmaceuticals. The technological capabilities and needs of societies of old restricted plant breeders to achieving modest objectives (e.g., product appeal, adaptation to production environment). It should be pointed out that these “older” breeding objectives are still important today. However, with the availability of sophisticated tools, plant breeders are now able to accomplish these genetic alterations in novel ways that are sometimes the only option, or are more precise and more effective. Furthermore, as previously indicated, they are able to undertake more dramatic alterations that were impossible to attain in the past (e.g., transferring a desirable gene from a bacterium to a plant!). Some of the reasons why plant breeding is important to society are summarized next.

**Why breed plants?**

The reasons for manipulating plant attributes or performance change according to the needs of society. Plants provide food, feed, fiber, pharmaceuticals, and shelter for humans. Furthermore, plants are used for aesthetic and other functional purposes in the landscape and indoors.

1. **Addressing world food, feed, and nutritional needs**

Plant breeding is needed to enhance the value of food crops, by improving their yield and the nutritional quality of their products, for healthy living of humans. Certain plant foods are deficient in certain essential nutrients to the extent that where these foods constitute the bulk of a staple diet, diseases associated with nutritional deficiency are often common. Cereals tend to be low in lysine and threonine, while legumes tend to be low in cysteine and methionine. Rice lacks pro-vitamin A (the precursor of vitamin A). An estimated 800 million people in the world, including 200 million children, suffer chronic under nutrition, with its attendant health issues. Malnutrition is especially prevalent in developing countries. Breeding is also needed to make some plant products more digestible and safer to eat by reducing their toxic components and improving their texture and other qualities. Toxic substances occur in major food crops, such as steroidal alkaloids in potatoes.

1. **Addressing food needs for a growing world population**

As the world population increases, there would be a need for an agricultural production system that is apace with population growth. Unfortunately, arable land is in short supply, stemming from new lands that have been brought into cultivation in the past, or surrendered to urban development. Consequently, more food will have to be produced on less land. With the aid of plant breeding, the yields of major crops have dramatically changed over the years. Another major concern is the fact that most of the population growth will occur in developing countries where food needs are currently most serious, and where resources for feeding people are already most severely strained, because of natural or human-made disasters, or ineffective political systems.

1. **The need to adapt plants to environmental stresses**

The phenomenon of global climatic change that is occurring over the years is partly responsible for modifying the crop production environment. This means that new cultivars of crops need to be bred for new production environments. Whereas developed economies may be able to counter the effects of unseasonable weather by supplementing the production environment, poor countries are easily devastated by even brief episodes of adverse weather conditions. For example, the development and use of drought-resistant cultivars is beneficial to crop production in areas of marginal or erratic rainfall regimes. Breeders also need to develop new plant types that can resist various biotic and other abiotic stresses in the production environment.

1. **The need to adapt crops to specific production systems**

Breeders need to produce plant cultivars for different production systems to facilitate crop production and optimize crop productivity. For example, crop cultivars must be developed for rain-fed or irrigated production, and for mechanized or non-mechanized production. In the case of rice, separate sets of cultivars are needed for upland production and for paddy production. In organic production systems where pesticide use is highly restricted, producers need insect- and disease-resistant cultivars in crop production.

1. **Developing new horticultural plant varieties**

The ornamental horticultural production industry thrives on the development of new varieties through plant breeding. Aesthetics is of major importance to horticulture. Periodically, ornamental plant breeders release new varieties that exhibit new colors and other morphological features (e.g., height, size, shape). Also, breeders develop new varieties of vegetables and fruits with superior yield, nutritional qualities, adaptation, and general appeal.

1. **Satisfying industrial and other end-use requirements**

Processed foods are a major item in the world food supply system. Quality requirements for fresh produce meant for the table are different from those used in the food processing industry. For example, there are table grapes and grapes bred for wine production. Different markets have different needs that plant breeders can address in their undertakings. For example, the potato is a versatile crop used for food and industrial products. Different varieties are bred for baking, cooking, fries (frozen) and starch. These cultivars differ in size, specific gravity, and sugar content, among other properties. High sugar content is undesirable for frying or chipping because the sugar caramelizes under high heat to produce undesirable browning of fries.

**Achievements of modern plant breeders**

The achievements of plant breeders are numerous, but may be grouped into several major areas of impact: yield increase, enhancement of compositional traits, crop adaptation, and the impact on crop production systems.

1. **Yield increase**

Yield increase in crops has been accomplished in a variety of ways including targeting yield *per se* or its components, or making plants resistant to economic diseases and insect pests, and breeding for plants that are responsive to the production environment. Yields of major crops (e.g., corn, rice, sorghum, wheat, soybean) have significantly increased in the USA over the years. For example, the yield of corn rose from about 2,000 kg/ha in the 1940s to about 7,000 kg/ha in the 1990s. In England, it took only 40 years for wheat yields to rise from 2,000 to 6,000 kg/ha. These yield increases are not totally due to the genetic potential of the new crop cultivars but also due to improved agronomic practices (e.g., application of fertilizer, irrigation). Crops have been armed with disease resistance to reduce yield loss. Lodging resistance also reduces yield loss resulting from harvest losses.

1. **Enhancement of compositional traits**

Breeding for plant compositional traits to enhance nutritional quality or to meet an industrial need are major plant breeding goals. High protein crop varieties (e.g., high lysine or quality protein maize) have been produced for use in various parts of the world. For example, different kinds of wheat are needed for different kinds of products (e.g., bread, pasta, cookies, semolina). Breeders have identified the quality traits associated with these uses and have produced cultivars with enhanced expression of these traits. Genetic engineering technology has been used to produce high oleic sunflower for industrial use, while it is also being used to enhance the nutritional value of crops (e.g., pro-vitamin A “Golden Rice”). The shelf-life of fruits (e.g., tomato) has been extended through the use of genetic engineering techniques to reduce the expression of compounds associated with fruit deterioration.

1. **Crop adaptation**

Crop plants are being produced in regions to which they are not native, because breeders have developed cultivars with modified physiology to cope with variations, for example, in the duration of day length (photoperiod). Photoperiod-insensitive cultivars will flower and produce seed under any day length conditions. The duration of the growing period varies from one region of the world to another. Early maturing cultivars of crop plants enable growers to produce a crop during a short window of opportunity, or even to produce two crops in one season. Furthermore, early maturing cultivars can be used to produce a full season crop in areas where adverse conditions are prevalent towards the end of the normal growing season. Soils formed under arid conditions tend to accumulate large amounts of salts. In order to use these lands for crop production, salt-tolerant (saline and aluminum tolerance) crop cultivars have been developed for certain species. In crops such as barley and tomato, there are commercial cultivars in use, with drought, cold, and frost tolerance.

**Future of plant breeding in society**

For as long as the world population is expected to continue to increase, there will continue to be a demand for more food. However, with an increasing population comes an increasing demand for land for residential, commercial, and recreational uses. Sometimes, farm lands are converted to other uses. Increased food production may be achieved by increasing production per unit area or bringing new lands into cultivation. Some of the ways in which society will affect and be affected by plant breeding in the future are as follow:

1. **New roles of plant breeding**. The traditional roles of plant breeding (food, feed, fiber, and ornamentals) will continue to be important. However, new roles are gradually emerging for plants. The technology for using plants as bioreactors to produce pharmaceuticals will advance; this technology has been around for over a decade. Strategies are being perfected for use of plants to generate pharmaceutical antibodies, engineering antibody-mediated pathogen resistance, and altering plant phenotypes by immunomodulation. Successes that have been achieved include the incorporation of *Streptococcus* surface antigen in tobacco, and the herpes simplex virus in soybean and rice.
2. **New tools for plant breeding**. New tools will be developed for plant breeders, especially, in the areas of the application of biotechnology to plant breeding. New marker technologies continue to be developed and older ones advanced. Tools that will assist breeders to more effectively manipulate quantitative traits will be enhanced.
3. **Training of plant breeders**. As discussed elsewhere in the book, plant breeding programs have experienced a slight decline in graduates in recent past. Because of the increasing role of biotechnology in plant genetic manipulation, graduates who combine skills and knowledge in both conventional and molecular technologies are in high demand. It has been observed that some commercial plant breeding companies prefer to hire graduates with training in molecular genetics, and then provide them with the needed plant breeding skills on the job.
4. **The key players in plant breeding industry**. The last decade saw a fierce race by multinational pharmaceutical corporations to acquire seed companies. There were several key mergers as well. The modern technologies of plant breeding are concentrated in the hands of a few of these giant companies. The trend of acquisition and mergers are likely to continue in the future.
5. **Yield gains of crops**. With the dwindling of arable land and the increase in policing of the environment by activists, there is an increasing need to produce more food or other crop products on the same piece of land in a more efficient and environmentally safer manner. High-yielding cultivars will continue to be developed, especially in crops that have received less attention from plant breeders. Breeding for adaptation to environmental stresses (e.g., drought, salt) will continue to be important, and will enable more food to be produced on marginal lands.
6. **The biotechnology debate**. It is often said that these modern technologies for plant genetic manipulation benefit the developing countries the most since they are in dire need of food, both in quantity and nutritional value. On the other hand, the intellectual property that covers these technologies is owned by the giant multinational corporations. Efforts will continue to be made to negotiate fair use of these technologies. Appropriate technology transfer and support to the poor third world nations will continue, to enable them to develop capacity