CHAPTER

1

Plant Breeding and its Scope

The sun is the ultimate source of energy for all living creatures on earth. Solar energy trapped by chlorophyll of the green plants, is the sole source of human food, fibre and fuel, either directly or indirectly. Thus, man has been concerned with plants since the beginning of the civilisation. With the development of science, the study of economic plants and their improvement has developed into a well-organised branch called 'plant breeding'. Ever since the beginning of agriculture, consciously or unconsciously, man has been creating genotypes, which are more efficient in trapping solar energy for converting it into food, fibre and fuel. Plant breeding is thus one of the earliest and foremost endeavours of man, which has led him towards civilisation and settled living.

1. DEFINITION

Plant breeding is concerned with developing varieties superior to existing ones. Frankel (1968) defined "*plant breeding is the genetic adjustment of plants to the social, cultural, economic and technological aspects of the environment*".

Several accomplishments of plant breeding can be cited to illustrate the above definition. The nutritional quality of several food plants has been upgraded by genetic means. For example, maize protein is poor in the essential amino acid called lysine. Probably this deficiency was responsible for the destruction of maize-based civilisations like Incas and Mayas of Latin America. Now, new maize varieties like *Protina*, *Shakti* and *HQPM* 7 were evolved by incorporating opaque-2 gene, which doubled the amount of lysine. Protein malnutrition is a curse to world population, particularly in developing countries. The protein content of major cereals, wheat and maize is being up-graded continuously. Breeding cotton varieties free of gossypol enables the use of cotton seed oil and protein for human consumption. This is genetic adjustment of crops to meet the needs of the society. Development of varieties with low neurotoxin in *Lathyrus*, low *trypsin* inhibitor in pulses, and low or zero *erucic* acid in rapes are the other goals and achievements of plant breeders. This adjustment upgraded the value of these crops to prevent nutritional disorders in human being. Golden rice rich in iron and vitamin A, Orange-Fleshed Sweetpotato varieties like *Sree Kanaka* and ST-14 with very high level of Beta carotene (Vitamin A) are produced by plant breeders to address health problems through biofortification.

Development of semi-dwarf varieties of rice and wheat, etc, has been primarily to enable the plant to respond to high doses of fertilizers and elevated levels of management, and yield more. Increased production named Green Revolution, mainly due to high yielding varieties, saved human population from starvation. Early maturing and photo insensitive varieties have been developed which fit into multiple cropping and various crop rotations. Development of fruit trees for high density orchards is yet another set of examples of genetic adjustment of plants for new cultural and economic arena. The mango variety Amrapali permits planting of twice the number of plants per hectare than older varieties. New apple varieties can be cultivated like tomatoes by staking and produce more fruit than wood. Thus plant breeders are able to produce tailor made designer varieties of plants to address any human need.

Under the prevailing socio-economic conditions in most developing countries, the agricultural technology most prevalent is the one, which involves labour intensive techniques. A good example of plant breeding under such conditions is the development of hybrid varieties of cotton, where hybrid seeds are produced by hand emasculation and pollination. The production of hybrid seeds in a hectare of cotton field provides employment for about 100 women for 80 days. Hybrid seed production of vegetables also set the same example of employment generation.

Now, here are a few examples to illustrate the genetic adjustment of plants to technological needs: development of a 'combine tomato' variety in the USA in which all fruits ripen at the same time to enable picking by a tomato combine. Similarly, in Australia pigeon pea varieties were developed which can be harvested with a combine harvester. Certain chemical treatments make some types of cotton cloth 'easy care'. Thus cotton varieties Hybrid 4, *Deviraj*, *Bhagya* and *Jayadhar* have been developed which are suitable for easy care treatment. Cotton fibre is white and to prepare coloured dress it is to be coloured with synthetic dye. Now cotton varieties with different colour like red, blue etc have been developed which does not need artificial colouring.

2. PLANT BREEDING AS AN ART AND SCIENCE

Ever since prehistoric man started cultivating plants, he first selected, consciously or unconsciously, superior plants from natural population. In the second phase he saved seed of his best plants for sowing next year. In a modest way this was the beginning of plant breeding. But there was no science in it; simply it was an art of selection. Plant breeding continued to be art up till the end of the 19th century when Mendelian Laws were rediscovered.

The modern technique of crop improvement developed on sound scientific basis only after the rediscovery of the Mendelian laws of inheritance. The contributions of other branches of science such as cytology, taxonomy, physiology, anatomy, biochemistry, biometry and now biotechnology towards the development of modern plant breeding technique can never be lost sight of. With the amalgamation of these different branches of basic sciences today, plant breeding has become a special branch of science dealing with evolving improved crop varieties and has been playing a pivotal role in the development of agriculture all over the world.

As the knowledge of plant genetics and related sciences progressed, the laws of inheritance were discovered and it became possible to reshuffle genes to tailor a desired plant type. Now with the biotechnological tools, it is possible to reshuffle genes among living organism. Thus, the art of plant breeding grew into a well knit science. The choice of parents based on knowledge of gene action, use of the most appropriate breeding methodology, analysis and interpretation of data are all science. Biometrical principles made even the art of selection fairly predictable. Therefore, as a science, plant breeding is only a little over 100 years old. But now plant breeding is more a science and less an art and involves more brain than brawn.

3. PLANT TYPE CONCEPT

Agriculture is the largest solar energy harvesting enterprise in the world. A part of the solar energy falling on the earth is trapped by green plants and converted into carbon compounds on which life of human race is dependent. Development of the plant canopy that can trap the maximum sunlight and produce maximum photosynthate vis-à-vis higher yield becomes an important consideration. This led to the concept of plant type or plant ideotype.

An ideotype can be defined as the required plant structure and developmental sequence of a plant which can best suit a particular environment for producing maximum economic return (Donald, 1968). Thus, the designing, breeding, testing and exploitation of plant ideotypes are logical steps towards new levels of yield. An ideotype provide a guideline to a breeder in the selection of the parents to be crossed and in the selection pressure to be imposed in the later generations. The ideotype may differ depending on species and systems of farming.

4. GOAL OF PLANT BREEDING

Providing a variety better than the existing one, has always been the aim of plant breeders. Thus, higher yield is and would remain the foremost goal followed by other attributes. Better quality in respect of taste, nutrition, suitability, industrial use, keeping quality, transportation and preservation-particularly in fruits, vegetables, flowers and food grains-are also important. Special quality in the produce, such as higher sugar recovery in sugarcane and sugarbeet; longer, finer and stronger fibre in cotton; more protein in pulses; more oil in oilseeds are other goals. Resistance to diseases, insect pests, cold and heat, flood and drought, adverse soil conditions and change in duration and suitability for new practices and possibilities are other goals. Environment resilient plant breeding is shaping the future course of this science.

Besides, any specific requirements of the consumer, the processor, the retailer and of course the nation, becomes the goal of the plant breeder. Naturally these goals are dynamic and keep on changing in time and space.

5. CONTRIBUTION OF PLANT BREEDING

5.1 Self-sufficiency in Food:

An English clergyman, Thomas Malthus, had predicted that unless checked by war or disease, the human population would grow so much that people would die of hunger by the end of the 19th century. This did not happen, and the main credit goes to agriculturists, particularly plant breeders, who met the food demand of the additional population by increasing crop productivity.

Similarly in the recent past India was classed among the countries which cannot be saved from starvation by any amount of world aid. Within a few years, however, the Green Revolution took place. Food production doubled due to the high yielding varieties of wheat, rice and other crops.

The production of food grains in 1977 grew so much that imports were stopped, old debts were paid and the country became self-sufficient. The Green Revolution triggered by high yielding varieties brought a complete change in production technology, marketing, storage and extension.

The productivity (kilogram per hectare) of all major food and fibre crops rose gradually 5 to 6 times (Table 1.1). This was all due to higher yielding varieties developed during the last 60 years in India. On the main strength of high yielding varieties, backed by area expansion and higher input use, production of food grains rose dramatically, from 61 million tons of 1950s to 230 million tons in 2012. India became net exporter of rice, wheat, maize and several other crops. Undoubtedly factors such as large area, better inputs, etc, played a role but high yielding varieties have contributed significantly to this quantum jump in production.

Table 1.1 Productivity (kg/ha) of major crops over last 60 years (Reserve Bank of India, 2013)

Year	Rice	Wheat	All cereals	Pulses	All food crops
1950–51	668	663	542	441	522
1960–61	1,013	851	753	539	710
1970–71	1,123	1,307	949	524	872
1980–81	1,336	1,630	1,142	473	1,023
1990–91	1,740	2,281	1,571	578	1,380
2000–01	1,901	2,708	1,844	544	1,626
2010–11	2,240	2,938	2,247	689	1,921
2012–13	2,462	3,119	2,450	786	2,125

5.2 Stabilising Production:

This can be achieved only by developing varieties, which can mitigate, to the extent possible, the adverse impact of aberrant weather, damage by pests, diseases and weeds. New varieties resistant to important diseases and pests are available in major crops, which indeed is a significant contribution of plant breeding. Resistant varieties do not require any fungicides or insecticides or other chemicals to protect them and thus environmental pollution is also avoided. Stabilised wheat production, for instance, is dependent on rust resistant varieties. In fact, the development of resistant varieties has been one of the biggest achievements of plant breeders to stabilize production.

5.3 Multiple Cropping

Development of short duration varieties of wheat, rice, pulses and oil seeds have made it possible to take 3-4 crops per year instead of 1-2 as in the past. Short duration urd (T-9) and mung (Pusa Baisakhi) varieties can now be cultivated in summer after wheat. Short duration pigeon pea varieties like Prabhat, Pant A-3, Bahar are harvested in six months instead of 11, and two crops can be grown instead of one in the same field. Many more new varieties of various crops are being developed which would fit in multiple cropping.

5.4 Tailoring Plant Characters

Plant breeders strive to achieve the best of all possible combinations of characters: plants with high yielding capacity, resistant to pests, weeds and diseases, tolerant to climatic stresses like cold, drought, water logging and submergence, amenability to local agronomic practices, resistant to storage pests and acceptable to consumers. Since most characters are governed by independent sets of genes, it is possible to recover, in crosses, segregants with desirable character combination. 'The plants of the world have a lot of wonderful genes if you can just find them and combine them', says Norman Borlaug. With the advent of the 'plant type' concept in plant breeding, plant structure has been so tailored to produce genotypes more responsive to better management. For example, traditional varieties of rice yield around 20 quintals but under better management, say 120 kg N/ha, would lodge and yield very low. The new dwarf varieties yield 60-80 quintals at 120 kg N/ha and under better management. The plant type of pigeon pea has been so changed as to make it smaller and more productive. Apple varieties have been developed at East Malling in U.K., which are not like old tall (100 m) and wood producing types but dwarf (1-2 m tall) and fruit producing types.

5.5 Extending the Boundaries of Cultivation

Newer varieties developed by plant breeders are adapted to wider areas and newer agroclimates. Cauliflower whose origin and domestication occurred under the temperate European climate has now yielded varieties, due to continued natural selection, which are adapted to tropical and sub-tropical conditions. These developments have taken place over a period of 40 years in India. Similar progress has been achieved in potato and tomato also.

5.6 More Nutrition per unit Area

Plant breeding has accomplished one very significant landmark; developing varieties which would produce more nutrition per unit of area. For example, the early sugarbeet varieties had about 4 percent sugar while there are varieties with 19 per cent sugar now. Multiplied by the higher root yield, the production of sugar per unit area has risen by 10 times. Similar is the example of oil production by some oil seed crops like safflower and protein by pulses. Since arable land area cannot be increased with the growing population, increased productivity becomes imperative and this is an important contribution of plant breeding.

6. TRAINING OF A PLANT BREEDER

Since a plant breeder is basically a biologist, he requires training in morphology, anatomy, cytology, systematic botany, embryology and physiology, particularly of crop plants. The knowledge of genetics is basic to him/her as the principles under lying plant breeding are basically dependent on the laws of inheritance. S/he should also acquire knowledge about evolution in crop plants and their domestication. A competent plant breeder has also to be a competent geneticist.

A plant variety must have resistance against pests and diseases. To develop a resistant variety, the breeder must have thorough understanding of plant pathology and entomology.

Statistics has helped plant breeders to compare large numbers of advanced lines, construct selection indices, and predict their performances. This area has developed into the biometrical approach to plant breeding. This is why in professional plant breeding, biometry is being emphasised.

Since experimental lines, breeding populations and materials for evaluation have to be grown using standard techniques. Hence knowledge of crop growing practices, and harvesting and processing technology is essential.

A plant breeder has to be trained in the nutritional quality of plant products since s/he is basically involved in upgrading the nutritional quality of the produce by genetic means.

In short, a plant breeder has to be a versatile person with a broad spectrum of knowledge of genetics, biotechnology, plant protection, crop husbandry, human nutrition, statistics and farm machinery. S/he is not necessarily expert in all these but should be in a position to apply the knowledge and experiences of the above disciplines in developing varieties.

7. USEFUL REFERENCES

Allard, R.W. 1960. *Principles of Plant Breeding*. John Wiley & Sons Inc., New York

Anon 1972. Genetic Vulnerability of Major Crops. NAS, Washington.

Anon. 2013. A Handbook of Agriculture. 6th edition. Indian Council of Agriculture Research, New Delhi

Balint, A . 1970. Protein Growth by Plant Breeding. Akademiai Kiado, Budapest.

Briggs, F.N. and Knowles, P.F. 1967. *Introduction to Plant Breeding*. Reinhold Publishing Corp.

Brown, L.R. 1970. Seed of Change-The Green Revolution and Development in the 1970's. Pall Mall Press, London.

Donald, C.M. 1968. The breeding crop ideotypes. Euphytica 17: 385-403.

Frankel, O. H. 1968. Third International Wheat Genetics Symp., Canberra, Australia.

RBI 2013. Handbook of Indian Economy. Reserve Bank of India, Mumbai

Simmonds, N. W. 1979. *Principles of Crop Improvement*. Longman, London and New York.

Singh, B. D. 2004. Plant Breeding: *Principles and Methods*. Kalyani Publishers, New Delhi.

Sneep, J. and Hendrikesen, A.J.T. (eds.) 1979. *Plant Breeding Perspectives*. Pudoc, Wageningen, Netherlands.