18BBO25A- ALLIED PAPER-II-PLANT STRUCTURE AND FUNCTIONS (FOR B.Sc ZOOLOGY STUDENTS)

UNIT-III- Plant Breeding: Aim, Scope and Significance. Selection (Mass and pureline), Hybridization

and Heterosis (Outline only). Plant

Biotechnology - Aim, Scope and Significance, introduction to Plant tissue culture and genetic

engineering.

PLANT BREEDING-INTRODUCTION, SCOPE AND IMPORTANCE

INTRODUCTION

- Plant breeding is an applied branch of botany whichdeals with improvement of Agricultural crops.
- Plant breeding science has crucial role to increase the productivity of the crop plants to fulfill the huge demandof the food.

Breeding new crops are important to develop new varieties which are high yielding, biotic and abiotic stresstolerance and better adaptability to different environmental and climatic conditions

Definition of Plant Breeding:

Man is almost absolutely dependent on plants for food. The things we eat virtually without exception are either plant materials or derived directly from plants. With the rapidly increasing population in the world the food supply is already grossly inadequate.

The solution of the problem lies in efforts to check the population growth and to increase food production.

Increased food production can be achieved by several methods for e.g., increasing the land area under cultivation, better agronomic practices, (including irrigation facilities fanned use of fertilizers), improved agricultural practices (including

more effective crop rotation, improved tillage methods, effective weed, disease and insect control) and by improved novel varieties of plants.

Plant breeding is concerned with developing varieties superior to existing ones.

It can be defined as a science, an art and a technology which deals with genetic improvement of crop plants in relation to their economic use for mankind.

Frankel (1968) defined plant breeding as the genetic adjustment of p ant to the Social, cultural, economic and technological aspects of the environment. Plant breeding is also called as crop improvement. A person changing and improving the heredity of plants is known as plant breeder.

Nature of Plant Breeding or What is Plant Breeding?

Plant breeding is the art and science of changing and improving the heredity of plants. In earlier days the extent of plant breeding as an art and as a science was much disputed Early Ln was a nomad and dependent for his food on the forest products.

As civilization progressed he learned to cultivate more plants and selected the seeds from healthier plants for sowing the next year. His method of selection was designed without an understanding of the principal of inheritance. Therefore, plant breeding then was largely an art (this selection is the earliest method of plant breeding and is practiced on a large scale, even today).

As man's knowledge about plants increased, he was able to select more intelligently with the discovery of sex in plants, knowledge about inheritance of characters role of environment in producing characters, the basis of variations in various plant characters addition of hybridization etc., plant breeding methods are based on scientific principles of plant science particularly of genetics and cytogenetics.

As the breeder's pledge of genetics and related plant sciences progressed, plant breeding became less of an art and more of a science. The modern plant breeding is, therefore, considered as science based upon a thorough understanding and use of genetic principles.

Aims and Objectives of Plant Breeding:

Plants are the basic source of food for the world's people. Over 50% of the world supply comes from the seven cereal grains, over 40% from rice and wheat (Fig. 3). Plants are also the original source of the food supplied by animal products.

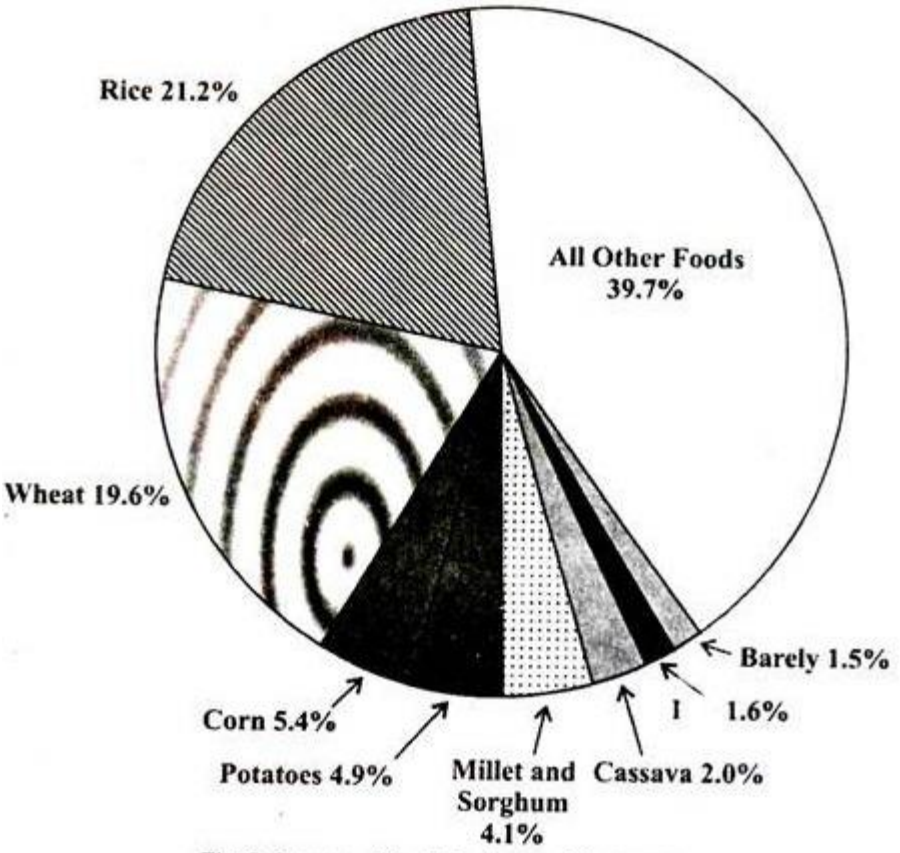

Fig. 3. Sources of food for the world's peop!:

Population is increasing very rapidly and the food supply is inadequate. In India, the tenth plan food grains target was 230 million tonnes in 2006-2007. The production was 212.9 million tonnes in 2001-02 and since then it has been declining. Trend of rice and wheat production was less than population growth by the end of the ninth plan.

Higher yields of food plants contribute to a more abundant food supply, a more profitable agriculture, and a lower cost of food products for the consumer. So, the primary objective of the plant breeding is to produce new crop varieties superior to existing types in all characters. The objectives of plant' breeding differs from crop to crop.

However, there are some objectives which are common in majority of field crops.
These are:

1. High Yields:

The ultimate aim of the plant breeder is to improve the yield of crop plants. It may be of grain yield, fodder field, fibre yield, tuber yield, cane yield or oil yield depending upon the crop species. It can be achieved by developing more efficient genotypes e.g., hybrid varieties of maize, sorghum, bajra etc.

2. Better Quality:

Quality of products determines its price and suitability for various uses.

Quality differs from crop to crop. It refers to:

i. grain size, colour, milling and baking quality of wheat

ii. cooking quality in rice.

iii. malting quality in barley

iv. stronger, longer and fine fibre in cotton

v. more protein contents in pulses and cereals

vi. lysine content in cereals

vii. nutritive and keeping quality in fruits, vegetables and flowers

viii. oil contents in oil seeds

ix. higher sugar contents in sugarcane and sugar beets

x. appealing flavour in apples

3. Disease and insect resistance:
Crop plants are attacked by various diseases and insects resulting in considerable yield loss. Development of resistant varieties can minimize such losses.

4. Abiotic resistance:
Crop plants also suffer from abiotic factors such as drought, soil salinity, cold and frost etc. The objective of the plant breeder should be to develop resistant varieties for such environmental conditions.

5. Photosensitivity and Thermo-sensitivity:
Development of photosensitive and thermo-sensitive varieties permits their cultivation in new areas. Rice is now cultivated in Punjab while wheat is a major rabi crop in West Bengal.

6. Early maturities:
Early maturity of crop reduces management period, insecticide spray and overall production cost. It also permits double cropping system. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation.

7. Synchronous maturities:
It refers to maturity of a crop species at a time. It is highly desirable in crops like mung (Vigna radiate) where several pickings are necessary.

8. Non-shattering characters:
The shattering of pods is a serious problem in a crop like mung. Hence, resistance to shattering is an important objective to plant breeders.

9. Non-shedding characters:
In arboreum cotton shedding of kapas after ball bursting is a serious problem. Locule retentive varieties have to be developed in this species of cotton.

10. Dormancy:
In some crops such as green gram, black gram, barley and pea, seeds germinate in the standing crop before harvesting if rains received. A period of dormancy in such cases would check the loss due to germination. In some other cases, however, it may desirable to remove dormancy.

11. Determinate Growth:
In crops like cotton, pigeon pea and mung, development of varieties with determinate growth is desirable.

12. Desirable Agronomic Characters:
One of the important objectives of plant breeding is to modify agronomic characters such as plant height, tillering habit branching, erect or tralg habit, growth habit etc.

Usefulness of these traits also differ from crop to crop Dwarfness in crop plants is generally associated with lodging resistance and fertilizer responsiveness e.g., wheat, rice, pearl millet, Sorghum etc. Tallness, high tillering and profuse branching are desirable characters in forage crops.

13 Varieties for New Season:
It is another important objective. To develop varieties for new seasons will solve the food problem, for example mung is now grown as a summer crop in addition to main kharif crop.

14. Removal of toxic compounds:
Some crops have toxic substances.

So it is essential to develop varieties free from toxic substances to make them safe for human consumption for e.g.
i. Removal of neurotoxin [B-N-Oxalylamine alanine, (BOAA)], from Khesan dal (Lathyrus sativus) which causes paralysis of lower limbs (lathyrism).

ii. Erucic acid from Brassica which is harmful for human health.

iii. Gossypol from seed of cotton to make them fit for human consumption.

. Brief History of Plant Breeding:

In 700 B C date palm was artificially pollinated by Assyrians and Babylonians. The first artificial interspecific plant hybrid was made by Thomas Fairchild in 1717. It is popularly known as **'Fairchild's mule'**.

It is obtained by crossing between sweet will am and carnation species of Dianthus. (Dianthus barbatus x D. caryophyllus). Thomas Andrew Knight (English, 1800) first used the artificial hybridization to produce many new kinds of fruits and garden crops Mendel (Austria, 1856-1864) performed hybridization experiments on pea plant.

He published results of his experiments as 'experiments in plant hybridization

In 1900 Mendel's laws were rediscovered by Hugo de Vries, a Dutch biologist Carl Correns', a German botanist, and Erich Van Tschermak, an Austrian botanist N.lsson (Sweden 1900) first elaborated plant selection method. Johanssen (Danish, 1903) developed the concept of pure line. Shull (U.S., 1903) proposed over dominance hypothesis of heterosis.

In 1914, he first used the term heterosis for hybrid vigour Vavilov (Russia 1926) identified 8 main centers and 3 sub centers of crop diversity. He also developed concept of parallel series of variation or law of homologous series of variation. Stadler (U.S., 1928) first used X-rays for induction of mutations in crop plants.

Hull (1945) coined the term recurrent selection and over-dominance working with maze. Borlaug (1953) first outlined the method of developing multiline in wheat.

In 1964, he developed high yielding semi-dwarf varieties of wheat, which resulted in **'green-revolution'**, Monsanto (U.S., 1997) first identified terminator gene, which allows germination of seed for one generation only. In 1998, he identified traitor gene, which responds to specific band of fertilizers and insecticides.

SELECTION

Selection is basic to any crop improvement. Isolation of desirable plant types from the population is known as selection. It is one of the twofundamental steps of any breeding programme viz., 1. creation of variation and 2. Selection. There are two agencies involved in carrying out selection : one is Nature itself (Natural selection) and the other is man artificial selection. Though both may complement each other in some cases, they are mostly opposite in direction since their aims are different under the two conditions (nature and domestication). The effectiveness of selection primarily depends upon the degree to which phenotype reflects the genotype.

Before domestication, crop species were subjected to natural selection. The basic for natural selection was adaptation to the prevailing environment. After domestication man has knowingly or unknowingly practiced some selection. Thus crop species under domestication were exposed to both natural and artificial selection i.e. selection by man.

For a long period, natural selection played an important role than selection by man. But in modern plant breeding methods natural selection is of little importance and artificial selection plays an important role.

Basic Principles of Selection : Notwithstanding the highly complex genetic situation imposed by linkage and espistasis, there are just three basic principles of selection (Walker, 1969) :

1. **Selection operates on existing variability** : The main function of the selection exercise is to discriminate between individuals. This is possible only when sufficient variation is present in the material subjected to selection pressure. Thus, selection acts on the existing variation it cannot create new variation.
2. **Selection acts only through heritable differences** : only the selected individuals are permitted to contribute to the next genetion / progenies. Therefore, should there be greater influence of non-heritable agencies on the individuals selected, the parent-progeny correlation will be greatly vitiated. Hence the variation among individuals to be selected must be genetic in nature, since it is the genetic variation that tends to close the gap between phenotype and genotype. Environmental variability cannot be of any use under selection.
3. **Selection works because some individuals are favoured in reproduction at the expense of others** : As a consequence of its past evolutionary history and breeding struc ture, a population or a crop consists of highly genetically variable individuals with regards to such diverse phenomena as differential viability, differential maturity, differences in mating tendencies, fecundity, and duration of reproductive capacity. Hence some individuals tend to become superior to others for some or other traits desirable under domestication. These superior individuals are retained for

reproduction while others discarded under selection.

Selection has two basic characterics viz.

1. Selection is effective for heritable differences only.
2. Selection does not create any new variation. It only utilizes the variation alreadypresent in a population.

The two basic requirements for select on to operate are :

1. Variation must be present in the population.
2. The variation should be heritable.

Selection intensity : Parcentage of plants selected, to be advanced to next generation, from a population.

Selection intensity I) It is the amount of selection applied expressed as the proportion of the population favoured (selected). The selection intensity is inversely proportional to the percentage proportion selected (PS), as reflectedin Table 1.

Table 1 : Relationship between selection intensity and proportion of population selected

Selection intensity (i)	2.64	2.42	2.06	1.76	1.40	1.16	0.97	0.80	0.34	0
% selected (PS)	1%	2%	5%	10%	20%	30%	40%	50%	80%	100%

Thus, larger the size of I, more stringent is the selection pressure (hence low fraction is selected) and vice versa. Then, no selection means all the members of a population are allowed to reproduce (I=0, PS=100%), and zero selection means the whole population is rejected (PS=0). However, in real selection experiments, as the desired alleles become preponderant after each cycle of selection, I is also changed.

The I is of the greatest consequence is bringing about changes in the gene frequency under selection. However, since the latter does not mean undue loss of desirable alleles, or undue load of population size, the choice of an arbitrary value of I may be hazardous in a plant breeding programme. The small size of I (i.e. low selection pressure) may cause a large population size to be handled in the next generation, which will unnecessarily be taxing on time and resources. On the other hand, a large size of I (high selection pressure) might cause allelic erosion due to genetic drift (i.e. changes in gene frequencies due to sampling error, or small sample size under selection in a finite population not due to genetic causes). Therefore, an appropriate level of I should be chosen based upon the range of variability present in the population subjected to selection.

The I=2.06 to 1.76 (i.e. around 5-10 per cent of individuals selected) has generally been found appropriate in plant populations. However, the limit of selection intensity is setby two factors : (i) population size, and (ii) inbreeding. Under natural selection, selection intensity is expressed as the relative number of offsprings produced by different genotypes,and is termed as selection coefficient.

Selection differential : Difference between the mean of the population and mean of the selected individuals. Expressed in terms of standard deviation and is designated as 'S' Selection differential (S) S is the average superiority of selected individuals over the mean of population of their origin. It is considered in the same parental generation before selection ismade. An arbitrary culling level, k(i.e. I) is fixed for a

trait and individuals beyond that levelare selected. The average of all such selected individuals can be designated by X. then the mean of selected individuals (X) exceeds the parental population mean by the measure of S.

That is S=X-μ. Therefore, wider the phenotypic variability (i.e. phenotypic variance, and phenotypic standard deviation, that measures variability), greater is the possibility of S being large.

Heritability : In crop improvement, only the genetic component of variation is important since only this component is transmitted to the next generation. The ratio of genetic varianceto the total variance i.e. phenotypic variance is known as heritability.

H = Vg / Vp

Vp = Vg+Ve Where Vp = phenotypic variance

Vg = genotypic variance

Ve + error variance of environmental variance

Heritability estimated from the above formula is known as the broad sense heritability. This is valid when homozygous lines are studied. But when segregating generations are studied genotypic variance consists of (a) additive variance (b) dominance variance (c) and variance due to epistasis.

Dominance variance is important when we are dealing with hybrids i.e. F_1 generations. In self pollinated crops we release varieties only after making them homozygous lines. Hence additive variance is more important in such cases. The proportion of additive genetic variance to the total variance is known as narrow sence heritability.

If heritability is very high for any character it can be improved. Improvement of characters with low heritability is very difficult.

Genetic Advance : Genetic advance is the difference between the mean of the selected plants in the original population and the mean of the progeny raised from the selected plants in the next generation. It can be predicted by the following formula.

Genetic advance(GA) = s P * H * K

K = selection intensity 2.06 when 5% of the population is selected

P = phenotypic standard deviation of the character in the population H = heritability in broadsense

MASS SELECTION

It is the earliest method of selection. Man has always practiced mass selection consciously or unconciously from the time of domestication. In its most basic form mass

selection consists of selecting individuals on the basis of phenotypic superiority and mixingthe seeds for using as planting material for next season.

Procedure for evolving variety by mass selection

First year : Large number of phenotypically similar plants having desirable characters are selected. The number may vary from few hundred to few thousand. The seeds from the selected plants are composited to raise the next generation.

Second year : composited seed planted in a preliminary field trial along with standard checks. The variety from which the selection was made should also be included as check. Phenotypic characterlistics of the variety are critically examined and evaluated.

Third to sixth year : The variety is evaluated in coordinated yield trials at several locations. It is evaluated in an initial evaluation (IET) trial for one year. If found superior it is promoted to main yield trials for 2 or 3 years.

Seventh year : if the variety is proved superior in main yield trials it is multiplied and released after giving a suitable name.

Modification of mass selection

Mass selection is used for improing a local variety. Large number of plants are selected (I year) and individual plant progenies are raised (II year). Inferior, segregating progenies are reflected. Uniform, superior rows are selected and the seed is bulked. Preliminary yield trials are conducted in third year. Fourth to seventh year multilocation tests are conducted and seed is multiplied in eight year and distributed in ninth year. Many other modifications also are followed depending on the availability of time and purpose for ehich itis used.

Merits of Mass selection :

1. Can be practiced both in self and cross pollinated crops
2. The varieties developed through mass selection are more widely adopted than purelines.
3. It retains considerable variability and hence further improvement is possible in future by selection
4. Helps in preservation of land races
5. Useful for purification of pureline varieties
6. Improvement of characters governed by few genes with high heritability is possible.
7. Less time consuming and less expensive.

Demerits of mass selection

1. Varieties are not uniform

2. Since no progeny test is done, the genotype of the selected plant is not known

Since selection is based on phenotype and no control over pollination the improvement brought about is not permanent. Hence, the process of mass selectionhas to be repeated not and then.

3. Characters which are governed by large number of genes with low heritability can notbe improved.
4. It can not create any new genotype but utilizes existing genetic variability.

Achievements

Mass selection must have been used by pre historic man to develop present daycultivated cross from their wild parents. It was also used extensively before pureline selection came into existence.

Cotton :

Dharwad

American

Cotton

Groundnu

t : TMV-1

& TMV-2

Bajra : pusa moti, Baja puri, Jamnagar gaint, AF_3

Sorghum : R.S. 1

Rice : SLO 13, MTU-15

Potato : K12

Methods in Plant Biotechnology:

i. Tissue and Cell Culture:

This technique helps in maintaining plant tissues for prolonged periods on an artificial culture/basal medium. Small group of cells is isolated and inoculated on a culture medium comprising carbohydrate source, vitamins, minerals and defined nitrogenous source(s) under sterilized lab conditions.

It is possible to cultivate any plant species using variable explants e.g. stem segment, leaf segment, pedicel, petiole, anther, pollen, microspores, petiole, cotyledons, endoperm, etc. Callus derived from a single initial group of cells can be sub-cultured, multiplied and in some instances induced to reinitiate differentiation of roots and shoots and thus form plantlets (Fig. 30-1). The latter are hardenend and then transferred to the soil.

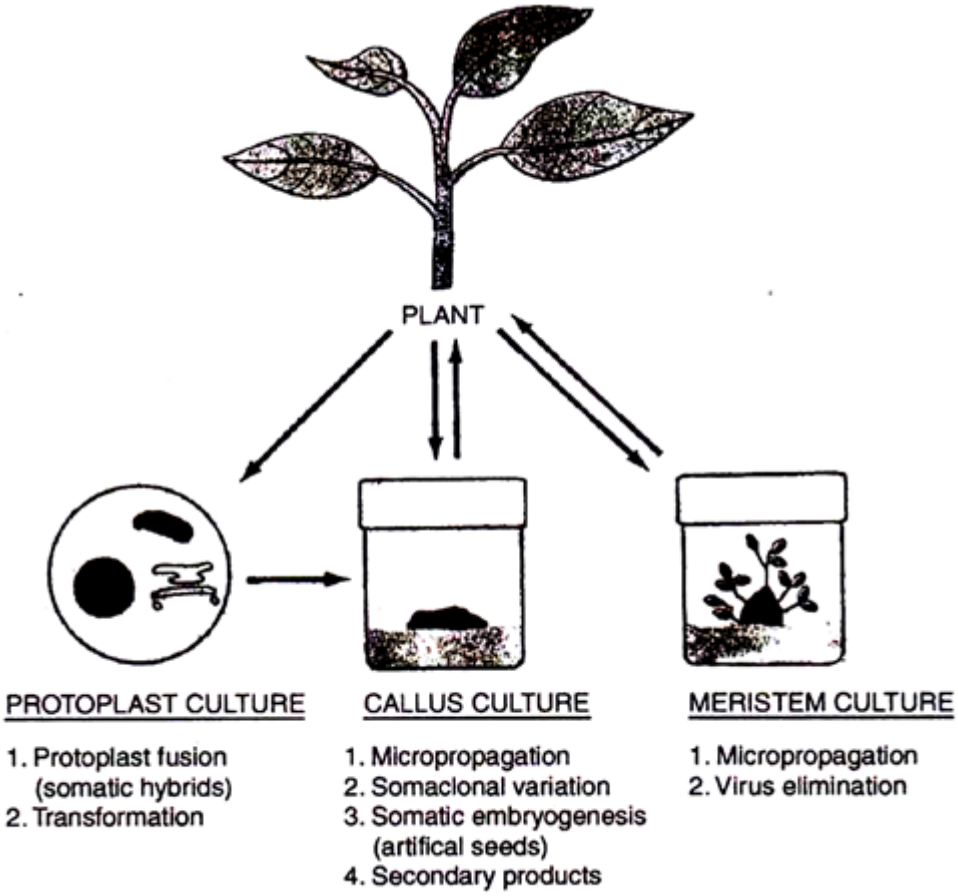

Fig. 30-1. Micropropagation and other uses of plant cultures.

Plant tissue culture is carried out on solid or liquid media. In the solid medium, agar or several other solidifying substance are added. In instance where tissue or lumps are agitated, they are disrupted from mass and then grown as clumps.

With a defined nutrition, phytochormones, specific light condition, some cells in culture differentiate into embryos called somatic embryos and these mature into plantlets comparable to the parent plant.

The somatic embryos of some plant species are used to raise artificial seeds which contains embryo enclosed in a gelatinous matrix (29-Plate 1). Currently, they are expensive but gradually they will become cost-effective when large scale production will be feasible. Presently only vegetable crops and ornamental plants are tackled.

Protoplast has been used for the study of several aspects in plant and cell biology; protoplast fusion, leading to somatic hybrids i.e. hybrids without involving fertilization or germ cells. Protoplast fusion also enables one to raise hybrids between genetically incompatible plants species.

Plants have cytoplasmic genomes that are maternally inherited and some of the genes are atrazine resistant are in the chloroplast, so is also cytoplasmic male sterility in the mitochondria, can be accomplished through protoplast fusion.

Such accomplishments have basic and applied importance. Protoplast fusion makes it possible to raise cytoplasmic-nuclear combinations without resorting to backcrossing required in traditional breeding. Removal of cell wall helps in direct transfer of genes into the plant cells.

ii. Recombinant DNA:

DNA recombination is insertion of DNA from one genome into DNA of another genome. It is a novel approach for recombination between unrelated organisms. Under natural conditions, recombination is only feasible between closely related species and has a minimal impact on the diversification of genetic information.

Comparatively rDNA technology is accomplished under in vitro conditions, permitting to overcome natural genetic barriers to recombine DNA from absolutely different species. Selection of specific DNA sequences, genes, for insertion into the host DNA is rapid and efficient than conventional method of plant breeding. Through this technique a foreign gene is introduced into a genome artificially and the resultant plant is said to be genetically engineered.

Three components are involved in genetic engineering and these are:

i. Source of 'foreign' gene—DNA sequence containing desired trait.

ii. A vector that carries the gene.

iii. A means of introducing the vector into the host plant.

Two methods are used to isolate gene. First, DNA having a specific gene of desire is cut into small fragments (restriction fragments) through specific enzymes i.e. restriction endonucleases.

The latter enzymes are isolated from bacteria that recognize and cleavage the double stranded DNA at specific sequences of four to eight nucleotides. The enzyme cleavages the entire genome of the cell from which the DNA was isolated, and this technique has the advantage of yielding large number of DNA fragments.

Many of these fragments will have only a portion of a gene or regions that are not normally transcribed. However, different species of bacteria produce many restriction enzymes with different specifies so it is feasible to produce a fragment having a particular gene of intention.

Second, mRNA is isolated from cells and used for direct synthesis of complimentary DNA (cDNA). The latter is synthesized from mRNA by reverse transcriptase, which uses mRNA as a temple to molecule.

In the next step the desired DNA is inserted into a vector which is usually double-stranded bacterial DNA called plasmid. Endonucleases are used to cut the plasmid and open it up (Fig. 30-2).

The ends of DNA are open where complementary plasmid DNA is inserted permitting the two DNA molecules to be mixed together. Their ends are joined with the DNA ligase. Thus, plasmid is a recombinant one having foreign gene and ready to be introduced into the host cells.

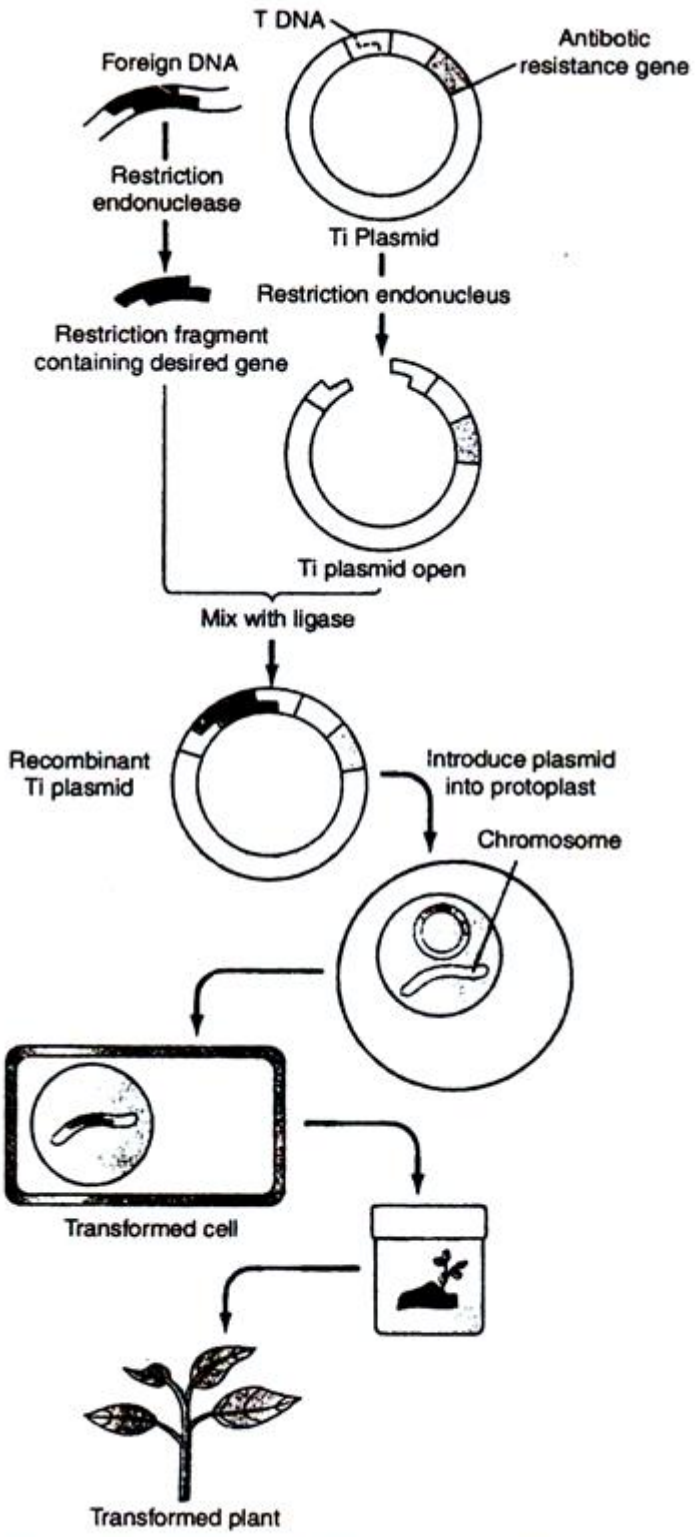

Fig. 30-2. Genetic engineering to transform plants with a foreign gene.

Ti plasmid is most commonly used as a vector to introduce foreign gene. Ti plasmid is from bacterium Agrobacterium tumifaciens which causes crown gall. In Ti plasmid there is a region called T-DNA which is normally integrated into the host cell DNA during infection.

T-DNA has the tumor- inducing genes that transform infected tissue into crown gall. The plasmid is usually ‘disarmed’ by clipping off the tumor-inducing genes and replacing them with the gene intended to be cloned.

Thus, the bacterium is made avirulent but it retains its capacity to infect and transform host plant cells. The vector plasmid also contains a gene for antibiotic resistance e.g. kanamycin resistance that permits selection of transformed cells.

Plant transformation is done either by co-cultivation with protoplast or by infection of leaf disks. In the former, dividing protoplasts are inoculated with bacteria having recombinant plasmid. After two or three days the bacteria are killed using antibiotics and protoplasts are permitted to divide further in clumps called microcalli. These are transferred to a medium containing antibiotic e.g. kanamycin.

Transformed calli carrying the resistant gene survive the antibiotic treatment. In the latter procedure, small disks cut from leaf surface are sterilized and incubated with a culture of A. tumifaciens permitting the bacteria to infect the wound cells of leaf cut surface. Again the bacteria are killed with antibiotic and recombined cells are selected.

Medium with determined nutrients and phytohormones is used to induce root and shoot formation. This is how a transformed plantlet is secured which carries and expresses the new gene and the introduced gene is passed to the next progeny.

In tumifaciens transformations the success rate is low and in monocots the accomplishments are nearly nil. There are other techniques which are used for the transfer of the foreign gene(s) and these are direct transfer method through particle gun, electroporation (which makes the cell permeable), microinjection of DNA, etc.

Successes and Potential of Plant Biotechnology:

i. Micro-Propagation:

Technique of micro-propagation is profusely used to raise large scale plant species. Here excised meristem is used and cultured in basal medium with nutrients, hormones and carbohydrate and nitrogen sources in an aseptic surroundings at low temperature.

Even axillary buds are used and new shoots produced are separated and sub-cultured to raise more axillary shoots and these are rooted and separate plantlets are obtained. Tissues can also be used to raise callus and subsequent organogenesis is induced to secure plantlets.

This technique has been successfully used to eliminate viruses and other pathogens from the micro-propagated plantlets and used for commercial purposes. The technique is of routine use in lilies, orchids, potato, vegetatively propagated plant species, some trees, etc.

In potato, sugarcane this technique is being exploited commercially to raise virus and pathogen-free plants and sell them commercially. Axillary and adventitious buds are used to raise plants in some timber trees, fruit cultivars and several of temperate fruit trees like apple, pear, peach are micro-propagated.

Sometime the micro-propagated plants show variable genetic traits due to somaclonal variation though it is not known how such types of chromosomal or genie variations are induced.

ii. Plant Protection:

Productivity or yield in a crop species depends on several factors including plant protection against various pathogens or insecticides. Further, weeds also reduce the yield by competiting with the crop plants. Through genetic engineering novel methods of crop protection against severe pests have been developed and chemical pesticides have been done away with.

iii. Herbicide Resistances:

In the crop productivity the weeds ground the crop plants reduce yield. Farmers, therefore, use herbicides for effective controlling them. This has led to side effects and some of the species have become herbicide resistant.

The gene for some enzymes has been introduced in some crop species and resistance against some herbicides has been engineered. Different approaches are used to introduce herbicide tolerance against various herbicides like glyphosate, glufosinate, atrazine, bromoxynil, oryzalin.

Herbicide	Gene/strategy used	Source	Transgenic developed
Glyphosate	EPSPS (overproduction)	*Petunia*	Petunia
			Tobacco
	aroA (mutated EPSPS)	*Salmonella*	Tobacco
		typhimurium	Tomato
			Poplar
	CP4 (tolerant EPSPS)	*Agrobacterium* spp.	Soybean
			Rapeseed
	Glyphosate oxidoreductase (detoxification)	*Achromobacter* spp.	Sugarbeet Maize, soybean & rapeseed
Phosphinothricin	*bar* (detoxification)	*Streptomyces hygroscopicus*	Tobacco
			Potato
			Alfalfa
			Rice
			Maize
			Papaya, Carberra-Ponce *et al. 1995*
	pat	*S. viridochromogenes*	Tobacco
Sulfonylureas	*csr 1-1*	*A. thaliana*	Rape
			Rice
	Sur B	Tobacco	Tomato
Imidazolinone	*imr 1*	*A. thaliana*	Tobacco
Atrazine	*psb A (mutant)*	*Solanum nigrum*	Soybean
Bromoxynil	*bxn*	*Klebsiella ozaenae*	Tobacco
			Tomato
			Cotton
Dinitroaniline	α-tubulin & β-tubulin	*Eleusine indica*	Tobacco

Resistance to Abiotic Stresses:

Poor harvest is attributed to drought, salinity, heat, flooding and freezing. Plants containing protective proteins or enzymes from other organisms which help the crop varieties to grow under adverse conditions are engineered. Osmolytes and osmoprotectants and saturation levels of membrane fatty acids are altered. Further the rate of scavenging of reactive oxygen intermediates is changed in transgenics.

Genes concerned with stress relief are introduced into various crop species achieving good degree of abiotic stress tolerance. Low molecular mass osmoprotectants and osmolytes e.g. amines, proline, sugar alcohols provide tolerance against stresses.

Thus, choline dehydrogenase has been isolated from E.coli and introduced in potato, tobacco and there is biosynthesis of glycine betaine and transgenic plants develop salt and freezing tolerance.

Stress	Gene/enzyme	Source plant	Transgenic
Drought, salinity & freezing	Dhydration response element- binding protein (*DREB1A)*	*Arabidopsis*	*Arabidopsis*
Osmotic	D-pyrroline-5-carboxylate synthetase (*p5cs)*	Moth bean (*Vigna aconitifolia)*	Tobacco
Drought & Salinity	Mannitol-1-phosphate dehydrogenase (*mltd)*	*E. coli*	Tobacco
Cold & Salinity	Choline oxidase (*cod A) globiformis*	*arthrobacter*	*Arabidopsis*
Salinity	Glyoxalase 1	*Brassica juncea*	Tobacco
Salinity	Na^+/H^+ antiport	*Arabidopsis*	*Arabidopsis*
Salinity	Choline dehydrogenase (*Bet A)*	*E. coli*	Tobacco
Cold	O-3-fatty acid desaturase (*Fad 7)*	*Arabidopsis*	Tobacco
Cold	Δ9-desaturase (*Des9)*	*Anacystis nidulans*	Tobacco
Drought	Trehalose-6-phosphate synthase (*TPS 1)*	Yeast	Tobacco
Drought	Levan sucrase (*Sac B)*	*Bacillus subtilis*	Tobacco
Salinity & drought	Lea protein (*HVA 1)*	Barley	Rice
Oxidative & chilling	Cu/Zn super oxide dismutase (Cu/Zn SOD)	Rice	Tobacco
Oxidative	Fe SOD	*Arabidopsis*	Maize
Chilling	ω-3-fattyacid desaturase (*Des 9)*	*Anacystis nidulans*	Tobacco
Freezing	Antifreeze protein (*Afp) (fish)*	Winter flounder	Tobacco
Oxidative	Mn-superoxide dismutase (*Mn-Sod)*	*Nicotiana plumbaginifolia*	Tobacco Alfalfa
Hypoxia & anoxia	Nonsymbiotic hemoglobin (vhb)	*Vitreoscilla stercoraria*	Tobacco
Hypoxia	Nonsymbiotic hemoglobin (hb)	Barley	Maize
Cadmium	Metallothionein-I (MT)	*Nicotiana glutinosa L.*	Tobacco

LEA (late embryogenesis abundant) proteins are encoded by HVA1 gene (from barley) and this is activated under abiotic stress and causes protective effect against osmotic stress. W-3-fatty acid desaturate (encoded by FAD 7 gene) and D9- desaturase (encoded by DES9 gene) leads to unsaturated fatty acids having cis-double bonds in membrane lipid especially in plastid membranes.

This confers chilling tolerance in many plant species. Antifreeze (afp) protein in some arctic fish induces chilling tolerance. In strawberry it inhibits ice crystal formation under chilling conditions. Another gene for glyoxylase-1 is shown to confer resistance against salt stress.

iv. Insect Pests and Disease Resistance:

Crop losses are incurred due to insect and plant diseases. It leads to enormous economic loses. Clearly management of pests is of prime importance in world agriculture. Traditional insecticides can kill the pests but also cause destruction of useful insects, and pollute the soil and subsoil water.