18. Back cross method and various modified methods

Backcross Method

In backcross method of breeding, the hybrid and the progenies in subsequent generations are repeatedly backcrossed to one of the parents. As a result, the genotype of the backcross progeny becomes increasingly similar to that of the recurrent parent. The objective of backcross method is to improve one or two specific defects of a high yielding variety.

Pre-requisite for back cross breeding

1. A suitable recurrent parent must be available which lacks in one or two characteristics.
2. A suitable donor parent must be available
3. The character to be transferred must have high heritability and preferably it should be determined by one or two genes.
4. A sufficient number of back crosses should be made so that the genotype of recurrent parent is recovered in full.

Application of back cross method

This method is commonly used to transfer disease resistance from one variety to another. But it is also useful for transfer of other characteristics.

1. Intervarietal transfer of simply inherited characters

E.g. Disease resistance, seed coat colour

2. Intervarietal transfer of quantitative characters.

E.g. Plant height, Seed size, Seed shape.

3. Interspecific transfer of simply inherited characters

E.g. Transfer of disease resistance from related species to cultivated species.

E.g. Resistance to black arm disease in cotton from wild tetraploid species into *G.hirsutum*

4. Transfer of cytoplasm

This is employed to transfer male sterility. The female parent will be having the sterile cytoplasm and recurrent parent will be used as male parent.

E.g. *Sesamum malabariucum* x *S.indicum*

Female parent Recurrent parent.

5. Transgressive segregation

Back cross method may be modified to produce transgressive segregants. The F_1 is backcrossed to recurrent parent for 2 to 3 times for getting transgressive segregants.

6. Production of isogenic lines

7. Germplasm conversion

E.g. Production of photo insensitive line from photo Sensitive germplasm through back crossing. This was done in the case of sorghum. Popularly known as conversion programme.

Procedure for backcross method

The Plan of backcross method would depend upon whether the gene being transferred is recessive or dominant. The plan for transfer of a dominant gene is simpler than that for a recessive gene.

First Year	Non-Recurrent		Recurrent	
	Parent B	x	Parent A	
	Resistant to rust		Susceptible to rust	
	F_1 Rr	x	rr	BC_1
	Resistant			
rr	Rr	x	rr	BC_2
rr	Rr	x	rr	BC_3
rr	Rr	x	rr	BC_4
rr	Rr	x	rr	BC_5

Back cross upto 6th or 7^{th} generation. After 7^{th} BC rust resistant lines are self pollinated. Harvest is done on single plant basis

8^{th} Season

Individual plant progenies grown

a) Homozygous plants having resistance and resembling parent A are selected harvested and bulked

9^{th} season

Yield trials.

10^{th} season

Seed multiplication and distribution

Steps

First Season

Hybridization

Crossing between parent B donor (Female) and Susceptible parent A recipient (male)

Second Season

Raising the F land backcrossed to recurrent parent A.

Third season

Growing the BC_lF_l. It will be segregating for 1 susceptible (rr): 1 resistant (Rr). Rust resistant plants are backcrossed with recurrent parent A. This is second backcross.

Fourth Season

Raising BC_2 F_1 will again segregate in the ratio of 1: 1. Third backcross is done with resistant plants.

Fifth Season to Eighth Season

Raising backcross F_ls and crossing resistant plants with recurrent parent is continued up to 7th backcross

Ninth season

Raising BC_7F_1 and observing resistant lines. The plants resembling parent A coupled with resistance is selected and harvested on single plant basis.

Tenth Season

Growing the progeny row8'and observing each row for resistance. Best rows are selected and harvest is done on row basis

Eleventh Season

The row bulk is raised in yield trial along with check and the best plots are selected.

Twelfth season

Selected plot seeds are multiplied and released as new variety.

Back Cross Method - Transfer of Recessive Gene

I Season	Non recurrent parent B	Recurrent parent A
Hybridization	Resistant	Susceptible
	Rr x	RR
	F_1 Rr	
II Season	Grow the F_1	
	Rr	

III Season Grow F2 RR " Rr " rr x RR BC_1

IV Season Grow BC_1F_1 Rr

V Season Grow BC_2F_2 RR : Rr : rr x RR BC_2

VI Season Grow BC_2F_1 Rr

VII Season Grow BC_2F_2 RR : Rr : rr x RR BC_3

VIII Season Raise BC_3F_1

IX Season Raise BC_3F_2 and it will segregate into 1:2:1 with resistant segregant make Backcross 4 (BC_4)

X Season Do as on VIII Season

XI Season do as in IX season

Continue this process still 7^{th} or 8^{th} backcross. After studying 8^{th} BCF_2 select plants resembling parent B coupled with resistance. Harvest them on single plant basis. Next season raise them in progeny rows and select beast progenies. Compare them in yield trial and fix the best culture, multiply it and release it as a variety. While selecting plants artificial bombardment for disease is to be done.

Steps

I Season: Make a cross between donor parent A and recurrent parent B and Harvest the hybrid. The donor parents A is resistant which is governed by recessive genes. The susceptibility is governed by dominant gene in parent B.

II Season: Grow the F1 which will be susceptible – Harvest them.

III Season: Grow F_2 which will be segregating in the ratio of I :2: I i.e. 3/4 susceptible and 1/4 resistant. With the resistant lines (rr) make first backcross with parent A having dominant RR gene. Harvest BC_I F_1

IV Season: Grow BC_IF_1

V season: Grow BC_1 F_2 which will be segregating as we saw in III season. Repeat the process of third season. This will give BC_2F1_I

VI Season : Grow BC_2F_1

VII season: Grow BC_2F_2 them repeat the process of V Season. This will give BC_3F_1.

VIII Season: Grow BC_3F_1

IX Season: Grow BC_3F_2 and repeat the process of VII Season. Harvest BC_4F_1.

X season: Grow BC_4F_1

XI Season: Grow BC_4F_2 and repeat the process of IX Season. Harvest BC_5F_1.

XII, XIII & XIV: Repeat the process and carry out backcross upto 7 time.

XV Season: While studying BC_7F_2 select single plants having resistance and resembling parent B.

XVI Season: Study the progenies in progeny rows and select best progenies.

XVII Season: Conduct yield trial and select best material.

XVIII Season: Multiply the seeds and distribute it as improved variety with resistance to disease.

Note: While studying back cross F_2s they should be bombarded with artificial epiphytotic conditions.

Merits of Backcross Method

- The genotype of the new variety is nearly identical with that of the recurrent parent, except for the genes transferred. Thus the outcome of a backcross programme is known beforehand, and it can be reproduced any time in the future.
- It is not necessary to test the variety developed by the back cross method in extensive yield tests because the performance of the recurrent parent is already known. This may save upto 5 years time and a considerable expense.
- The backcross programme is not dependent upon environment, except for that needed for

the selection of the character under transfer. Therefore, off-season nurseries and green - houses can be used to grow 2-3 generation each year. This would drastically reduce the time required for developing the new variety.

- Much smaller population are needed in the backcross method than in the case of pedigree method.
- Defects, such as, susceptibility to disease, of a well-adapted variety can be removed without affecting its performance and adaptability. Such a variety is often preferred by the farmers and the industries to an entirely new variety because they know the recurrent variety well.
- This is the only method for interspecific gene transfers.
- It may be modified so that transgressive segregation may occur for quantitative' characters.

Demerits of Backcross Method

1. The new variety generally cannot be superior to the recurrent parent, except for the character that is transferred.
2. Undesirable genes closely linked with the gene being transferred may also be transmitted to the new variety.
3. Hybridization has to be done for each backcross. This is often difficult, time taking and costly.
4. By the time the backcross is over, the recurrent parent may have been replaced by other varieties superior in yielding ability and other characteristics.

Number of Plants Necessary in the Backcross Generations

According to the above schemes, only a few (about 10) seeds are necessary in each backcross generation for the transfer of a character governed by a single gene. This population size would almost certainly have at least one plant with the gene for rust resistance. However, if the character is governed by two or more genes, a larger number.

of backcross progenies would be required. A larger size of backcross population is also desirable to permit an effective selection for the plant type of the recurrent parent, and to increase the probability of recombination between the genes being transferred and the genes tightly linked with it. Therefore, more than 50, preferably 100 or more, plants should be grown in each backcross generation. In F2 and F3 generations, the population size should be as large, as possible.

Selection for the Character Being Transferred

A rigid selection for the character being transferred must be practiced during the backcross and the F2 generations, otherwise the character is likely to be lost. It is, therefore, essential that the character being transferred must have a high heritability. Although monogenic characters are the easiest to transfer, the number of genes is not as important as the heritability of the character under transfer.

It is desirable that the character should be easily identified either visually or through simple tests. The breeder should try to maintain the character in an intense form through selection. Often the intensity would be lost due to modifying genes in the new genetic background. Therefore, the nonrecurrent parent should be chosen for a high intensity of the character to be transferred.

Number of Backcrosses to be made

In the backcross method, it is essential that the genotype of the recurrent parent should be recovered except for the gene being transferred. The recurrent parent is likely to consist of several closely similar purelines. Therefore, a sufficient number of plants from the recurrent parent should be used for the backcrosses. This would make sure that the new variety will have the same genetic composition as the recurrent parent.

Generally, six backcrosses are sufficient to recover the essential feature of the recurrent parent. Selection for the characteristics of the recurrent parent, particularly in the early backcross generations, may often have the effect of one or two additional backcrosses. Thus six backcrosses along with selection for the recurrent parent plant type in the early backcross generations will be effective in recovering the genotype of the recurrent parent.

Modifications of the Backcross Method

The backcross method may be modified in various ways to suit the needs of the breeder. Following are the three common modifications of the backcross method.

Production of F_2 and F_3

The F_2 and F_3 generations are produced after the first and the third backcrosses. A rigid selection for the character being transferred and for the characteristics of the recurrent parent is done in the F_2 and F_3 generations. In the backcross progenies, selection need not be done either for the character being transferred or for the characteristics of the recurrent parent. The fourth, fifth and sixth backcross are made in succession. For the sixth backcross, a relatively larger number of plants from the backcross progeny is used. This method may be used for the transfer of both dominant and recessive genes. It is believed that an effective selection in F_2 and F_3 generations is equivalent to one or two additional backcrosses.

Backcross - Pedigree Method

In this method, the hybrid is backcrossed 1-2 times to the recurrent parent. Subsequently, the backcross progenies and handles according to the pedigree method. This approach is useful when one of the parents is superior to the other in several characteristics but the non recurrent parent is not desirable agronomically. The superior parent is used as the recurrent parent.

The purpose of the one to two backcrosses is to make sure that the new variety would get a majority of the superior genes from the recurrent parent. It also leaves enough heterozygosity for transgressive segregants to appear. The varieties developed by this method must be put to yield trials as those developed by the pedigree method. The same holds true when two or more recurrent parents are used in the backcross programme.

Application of the Backcross Method to Cross Pollinated Crops

The backcross method is equally applicable to cross-pollinated crops. The method is essentially the same as in the case of self-pollinated crops. The only difference is that in cross-pollinated crops a large number of plants (100-300) from the recurrent parent must be used in each backcross.

This is necessary so that the new variety has the same genetic constitution as the recurrent parent. For example, wilt resistance was transferred to alfalfa variety California Common from the variety Turkestan. Two hundred plants of California Common were used for each backcross. The new variety Calliverde is exactly like California Common except for its wilt resistance.

Comparison between Pedigree and Backcross Methods

S. No.	Pedigree method	Backcross method
1.	F_1 and the sub sequent generations are allowed to self-pollinate	F_1 and the subsequent generations are backcrossed to the recurrent parent
2.	The new variety developed by this method is different from the parents in agronomic and other characteristics	Usually extensive testing is not necessary before release
3.	The new variety has to be extensively tested before release	Usually extensive testing is not necessary before release
4.	The method aims at improving the yielding ability and other characteristics of the variety	The method aims at improving specific defects of a well adapted, popular variety
5.	It is useful in improving both qualitative and quantitative characters	Useful for the transfer of both quantitative and qualitative characters provided they have high heritability
6.	It is not suitable for gene transfer from related species and for producing substitution or addition lines	It is the only useful method for gene transfers from related species and for producing addition and substitution lines
7.	Hybridization is limited to the production of the F1 generation.	Hybridization with the recurrent parent is necessary for producing every backcross generation
8.	The F_2 and the subsequent generations are much larger than those in the backcross method	The backcross generation are small and usually consist of 20-100 plants in each generation
9.	The procedure is the same for both dominant and recessive genes	The procedures for the transfer of dominant and recessive genes are

		different.

Multiline Varieties

Generally, pureline varieties are highly adapted to a limited area, but poorly adapted to wider regions. Further, their performance is not stable from year to year because of changes in weather and other environmental factors. Purelines often have only one or a few major genes for disease resistance, such as, rust resistance, which make them resistant to some races of the pathogen. New races are continuously produced in many pathogens, which may overcome the resistance present in the pureline varieties. For example, Kalyan Sona wheat *(T.aestivum)* originally resistant to brown rust (leaf rust), soon became susceptible to new races of the pathogen.

To overcome these limitations, particularly the breakdown of resistance to disease, it was suggested to develop multiline varieties. Multiline varieties are mixtures of several purelines of similar height, flowering and maturity dates, seed colour and agronomic characteristics, but having different genes for disease resistance. The purelines constituting a multiline variety must be compatible, i.e., they should not reduce the yielding ability of each other when grown in mixture.

In 1954, Borlaug suggested that several purelines with different resistance genes should be developed through back cross programmes using one recurrent parent. This is done by transferring disease resistance genes from several donor parents carrying different resistant genes to a single recurrent parent. Each donor parent is used in a separate backcross programme so that each line has different resistant gene or genes. Five to ten of these lines may be mixed depending upon the races of the pathogen prevalent in the area. If a line or lines become susceptible, they would be replaced by resistant lines. New lines would be developed when new sources of resistance become available. The breeder should keep several resistant lines in store for future use in the replacement of susceptible lines of multiline verities.

Merits of Multiline varieties

1. All the lines are almost identical to the recurrent parent in agronomic characteristics, quality etc. Therefore, the disadvantages of the pureline mixtures are not present in the multiline varieties.

2. Only one or a few lines of the mixture would become susceptible of the pathogen in anyone season. Therefore, the loss to the cultivator would be relatively low.
3. The susceptible line would constitute only a small proportion of the plants in the field. Therefore, only a small proportion of the plants would be infected by the pathogen. Consequently the disease would spread more slowly than when the entire population was susceptible. This would reduce the damage to the susceptible line as well.

Demerits of Multiline Varieties

1. The fanner has to change the seed of multiline varieties every few years depending upon the change in the races of the pathogen.
2. There is a possibility that a new race may attack all lines of a multiline variety.

Achievements

Multiline variety appears to be a useful approach to control diseases like rusts where new races are continuously produced. In India, three multiline varieties have been released in wheat *(T.aestivum)*. Kalyan Sona, one of the most popular varieties in the late sixties, was used as the recurrent parent to produce these varieties. Variety 'KSML 3' consists of 8 lines having rust resistance genes from Robin, Ghanate, Kl, Rend, Gabato, Blue Brid, Tobari etc. Multiline 'MLKS 11' is also a mixture of 8 lines; the resistance is derived from E 6254, E 6056, E 5868, Frecor, HS 19, E 4894 etc. The third variety, KML 7406 has 9 lines deriving rust resistance from different sources.

Dirty Multiline

This term is used when a multiline is having one or two susceptible lines also. The idea of including susceptible lines is to prevent race formation.