B. Bulk Method

After hybridization programme when the F_2 and subsequent generations are harvested in mass or as bulk to raise the next generation, it is called **bulk method.** At the end of bulking period, individual plants are selected and evaluated in the same manner of pedigree method.

This method is applicable to any self pollinating crop like cereals, legumes and oil seeds. Three different **advantages** may be achieved from this method: (1) isolation of homozygous lines, (2) waiting for selection by environmental disaster, (3) the long period of bulking may be helpful for natural selection to change the composition of population.

Procedure

First Year: Hybridization is done between the selected parents with the desirable attributes. The cross may be simple or complex depending upon the number of selected parents.

Second Year: The **F_1 generation** seeds are space planted and seeds from these plants are harvested in bulk.

Third Year to Seventh Year: Starting from **F_2 generation** onwards the seeds are planted at commercial seed rate and spacing. The seeds of subsequent generations are

harvested in bulk. Many environmental factors, disease outbreak, etc., may select out the particular genotype from this bulk population. The population size in each generation should be large always, 30,000 - 50,000 plants in each generation.

Eighth Year: **F_7 generation** seeds are space planted and superior phenotypes are selected and harvested separately. The selection is made on disease reaction, grain character, etc.

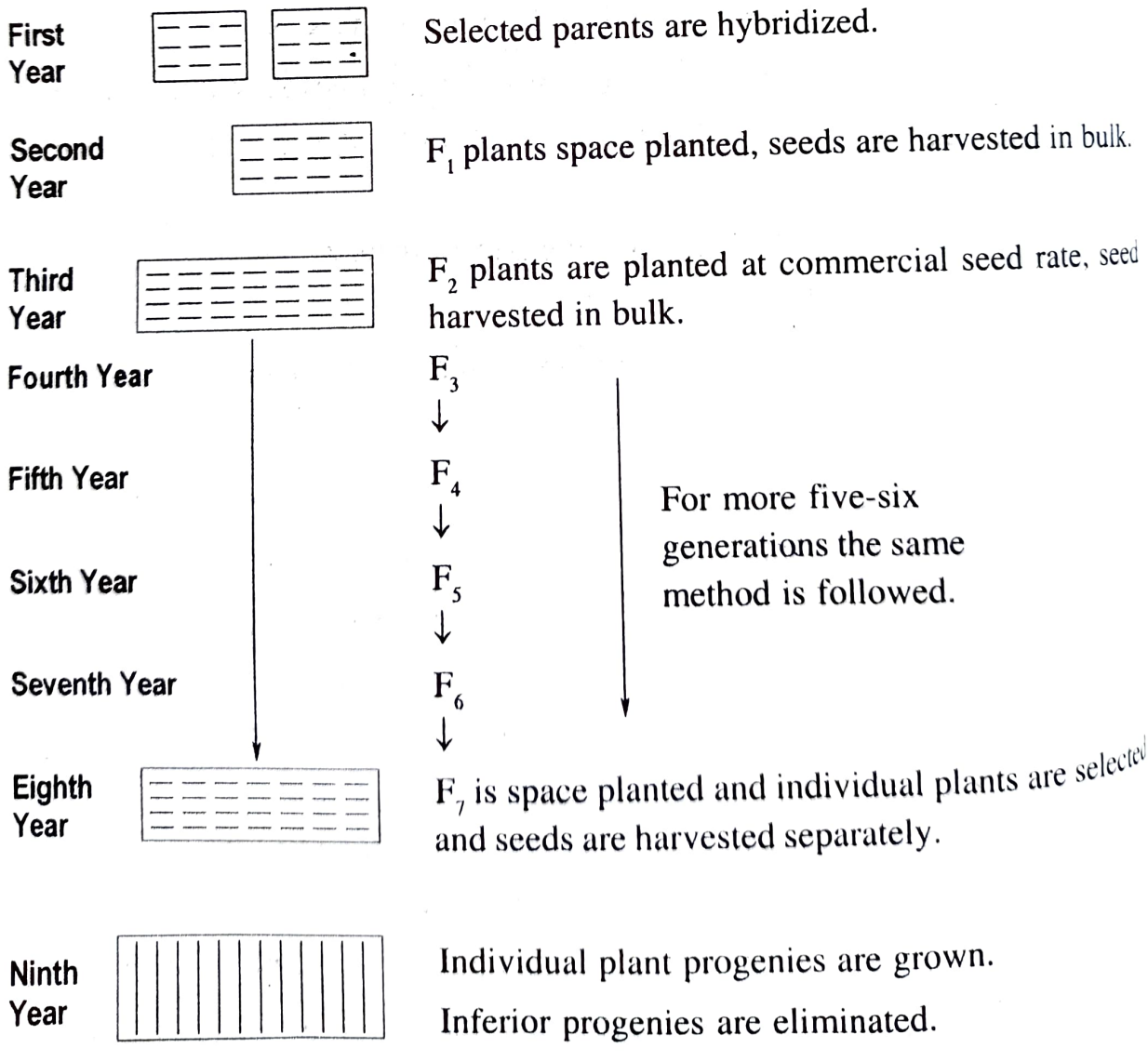
Ninth Year: Individual plant progenies of **F_8 generation** are grown in single or multi-row plots. Weak or inferior progenies are rejected, only 100-300 plant progenies are selected which are superior as well as showing no segregation.

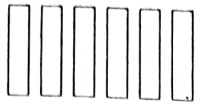
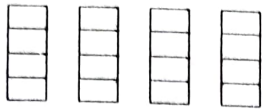
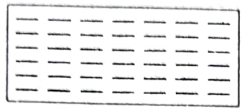
Tenth Year: Preliminary yield trial is conducted with **F_9 generation** with standard commercial variety as check. The undesirable progenies are rejected.

Eleventh To Fifteenth Year: **Replicated yield trial** at several locations is carried out using standard commercial variety. The lines are evaluated for some important characteristics in addition to yield, disease resistance, etc.; superior lines are released as new variety.

Sixteenth Year: The seeds are **multiplied** and **distributed** to the farmer.

Schematic representation:



Tenth Year		Preliminary yield trials using standard varieties as check.
Eleventh to Fifteenth Year		Multilocation yield trials for the selected progenies.
Sixteenth Year		Multiplication of seed for distribution.

Merits

1. This method is simple, convenient and less expensive.
2. The natural disease epiphytotics, winter killing, etc., eliminate the undesirable types and increase the frequency of desirable types, which is more helpful for isolation of desirable types.
3. As natural selection acts here, so the progenies selected from long term bulk are far superior than those selected from F_2 of short term bulk.
4. Less attention and labour is needed for this method.
5. Since large populations are grown, the transgressive segregants are more likely to appear and there is greater chance of isolation of transgressive segregants in this method.
6. Artificial selection may be practised to increase the frequency of desirable types.
7. Survivability of any gene or a particular genotype can be studied in this method.

Demerits

1. This method takes a long time to release a new variety, as the method of natural selection becomes operative only after F_8 or F_{10}.
2. The short term bulk method is useful for isolation of homozygous lines but the effect of natural selection has little effect on the genetic composition of the population.
3. Breeder has little opportunity to show his skill in this method, practically selection is mainly based on natural selection.
4. Inheritance of characters is not individually maintained as in pedigree method.
5. At the end of bulking period a large number of progenies are being selected.

Achievements

This method has been used to a limited extent due to lack of popularity. In U.S.A the barley varieties like Arivat, Beecher, Glacier and Gem have been originated from a bulk population derived from cross Atlas × Vaughn, the bulk was maintained in this case for 7 generations.

As this method requires more time to get the effect of natural selection for developing a new variety and the lack of using any skill of breeder for selection of superior types, this method is less used by the breeder for crop improvement.

Comparison between Bulk and Pedigree Method

Pedigree Method	Bulk Method
1. The desirable plants are selected in F_2 and individual plant progenies are grown in subsequent generations.	1. No selection is made in F_2 and the subsequent generations are maintained as bulk.
2. Artificial selection, artificial disease epidemics, etc., are the integral part of this method.	2. Natural selection is operative here which determines the composition of population at the end of bulking period.
3. Pedigree record of each progeny is maintained in such a way that even the finally selected progeny can be traced back to the particular F_2 plant.	3. No pedigree records are maintained.
4. It requires close attention of a breeder from F_2 generation onward as in each generation selection and pedigree records are maintained.	4. It is simple, convenient and overall requires less attention of the breeder during the period of bulking.
5. More laborious, time consuming and expensive.	5. Less laborious and less expensive.
6. The undesirable segregants are rejected in each generation specially in F_2.	6. As there is no selection in F_2 onwards, so there is no rejection of segregants also.
7. The size of the population is usually smaller than in the case of bulk method.	7. Generally large populations are grown. Natural selection is expected to play the role to select the transgressive segregants.
8. This method is more scientific, popular and widely used.	8. This method is not so popular and less used by the breeder.

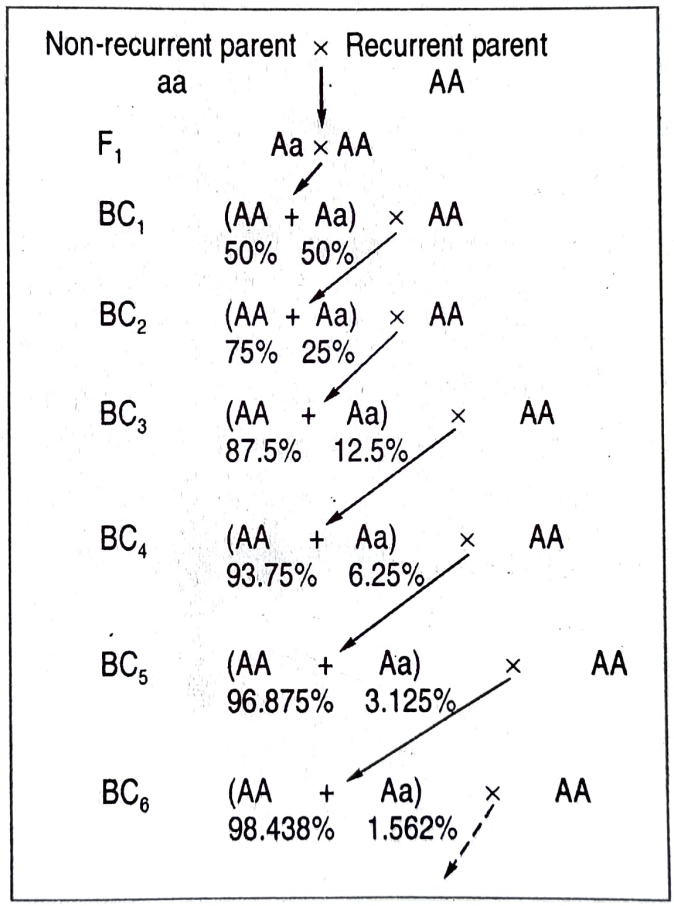
C. Back-cross Method

Back-cross is the event of crossing of F_1 with either of the parents, but here in the back-cross method of breeding the hybrid is to be crossed with the superior parent whose genotype is to be transferred to the local variety. For example, in a particular area there is

a well adapted high yielding local variety but susceptible to a particular disease, this variety will be considered as **recipient parent**. The disease resistant variety will be the **donor parent**. The recipient parent will be used in this method of breeding repeatedly to get all the genes to be transferred which is also known as **recurrent parent** and the donor parent is known as **non-recurrent parent**.

Genetic consequences of repeated back-crossing

Repeated back-crossing results in decreasing the frequency of heterozygosity by 50% in each subsequent generation and rapid increase in homozygote, upto 98% by sixth back cross progeny, will be achieved. The genotype of the back-cross progeny becomes increasingly similar to that of the recurrent parent.



Procedure

The plan of back-cross method differs on the gene which is to be transferred, whether it is dominant or recessive.

(a) Transfer of dominant gene

Selection of parents : Variety A — Recurrent parent (well adapted, high yielding); Variety B — Non-recurrent parent, dominant gene controlled (stem rust resistant).

Hybridization (First Year): The recurrent parent (variety A) should be used as female parent and the non-recurrent parent (variety B) as male parent.

F_1 generation (Second Year): F_1 plants are back-crossed to variety A, in this generation all the plants are heterozygous for rust resistant character.

BC_1-generation (Third Year): 50% of the BC_1 plants which are resistant are selected and back-crossed to the recurrent parent, i.e., variety A.

BC_2-BC_5 generation (Fourth-Seventh Year): In each back-cross generation, segregation would occur for rust resistance. Rust resistant plants are selected and back-crossed to recurrent parent, variety A.

BC_6-generation (Eighth Year): The plants of this generation will have 98.4% genes from variety A. Rust resistant plants are selected and selfed. Their seeds are harvested separately.

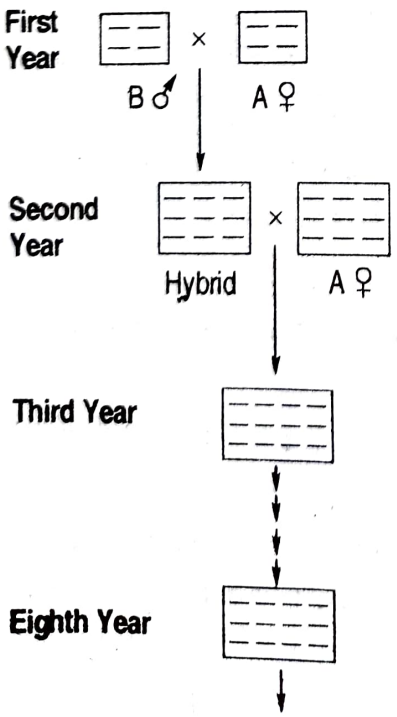
BC_6-F_2 generation (Ninth Year): Individual plant progenies of selfed plants are grown separately. The rust resistant plants are selected and the seeds are harvested separately.

BC_6-F_3 generation (Tenth Year): Individual plant progenies are grown. The plants homozygous for rust resistance and similar to the plant type variety A are harvested in bulk.

Yield test (Eleventh Year): The new variety is tested in replicated yield trial along with the variety A as a check, as the new variety will be same in performance with variety A only with rust resistant character.

Twelfth Year: Seed multiplication is done and distributed to the farmers.

Schematic representation:



Hybridisation between variety A and B.

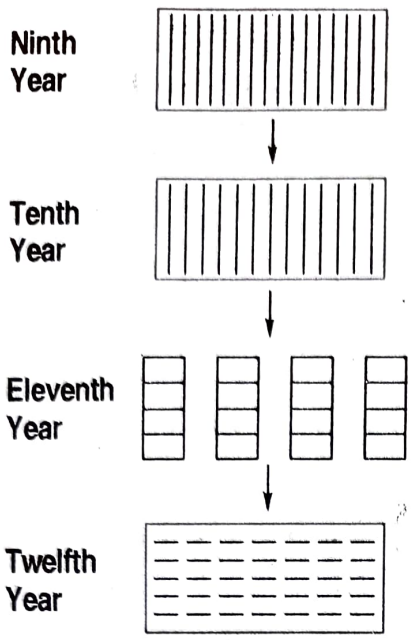
A is the recurrent parent, B is non-recurrent.

The hybrid plant is back-crossed with recurrent parent A.

The plants are selected which are rust resistance as well as similar to recurrent parent A.

$BC_2 - BC_5$ — Same procedure is followed for every year.

BC_6 — Rust resistant plants are self pollinated. The seeds are harvested separately.



Individual plant progenies are grown.

The rust resistant plants similar to plant type A are selected.

Individual plant progenies are grown.

Homozygous progenies similar to recurrent parent A are harvested and bulked.

Replicated yield trial with recurrent parent as one of the check.

Seed multiplication and distribution.

(b) Transfer of recessive gene

Procedure for transferring a **recessive gene** will be different from that of dominant gene, as the recessive gene will be expressed only in homozygous condition. So the selection for that recessive gene requires the F_2 generation, i.e., selfing is needed after every two back-crosses, and testing for the presence of that character has to be done in that generation.

Selection of parents: The parents are selected in this programme as the previous one, only difference is that the rust resistance is a recessive gene controlled character.

Hybridization (First Year): The recurrent parent is used as female parent and hybridized with the rust resistant donor plant.

F_1 generation (Second Year): The F_1 plants won't be rust resistant, these will be back-crossed to the recurrent parent.

BC_1 generation (Third Year): Here also no rust resistant plants will appear, so no need to do any rust susceptibility test. All the plants are selfed.

BC_1-F_2 generation (Fourth Year): The plants are tested for rust resistance character. These plants are selected and back-crossed with recurrent parent.

BC_2 generation (Fifth Year): There is no rust resistance test, the plants are selected only on resemblances with recurrent parent A, and again back-crossed with recurrent parent.

BC_3 generation (Sixth Year): Again the plants are self-pollinated, but without any selection for resistance character.

BC_3-F_2 generation (Seventh Year): The selection for rust resistance is done in this generation. The rust resistant plants having resemblance with variety A are selected and back-crossed.

BC_4 generation (Eighth Year): Same as BC_2 generation.

BC_5 generation (Ninth Year): Same as BC_3 generation.

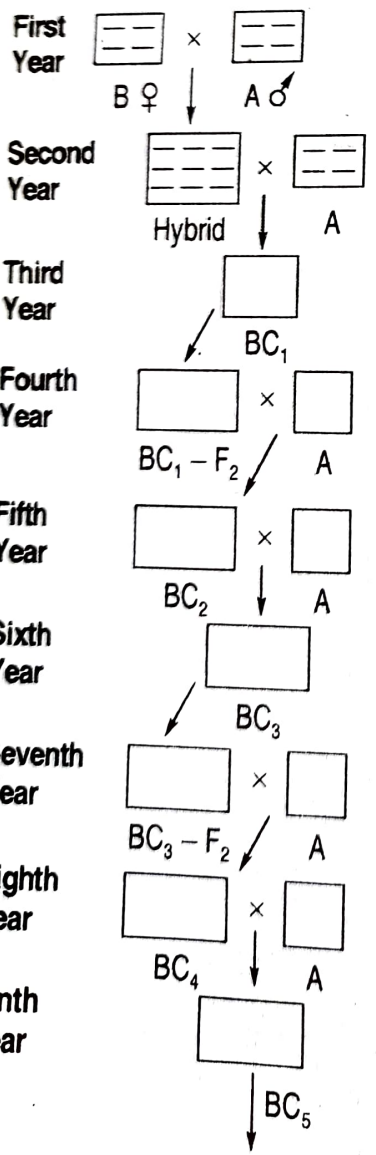
BC_5-F_2 generation (Tenth Year): Plants are selected against rust resistance and also the characters of variety A. The selfed seeds from the selected plants are harvested separately.

BC_5-F_3 generation (Eleventh Year): Individual plant progenies are grown and subjected to rust resistance test. Rigid selection is done for resistance to stem rust and the characteristic of variety A. Seeds from selected plants are mixed together to constitute the new variety.

Yield test (Twelfth Year): The variety is tested in replicated yield trial along with the variety A as check. The new variety should be same in yield performance except bearing the new character introduced.

Thirteenth Year: Seed multiplication and distribution to the farmers are carried out.

Schematic representation:



Hybridization between variety A and B.

A is recurrent parent, B is with recessive rust resistance gene.

F_1 is back-crossed with recurrent parent.

No rust resistance test.

No rust resistance test.

The plants are all self pollinated.

The rust resistant plants are selected and back-crossed with recurrent parent.

No rust resistance test.

The plants are back-crossed with recurrent parent.

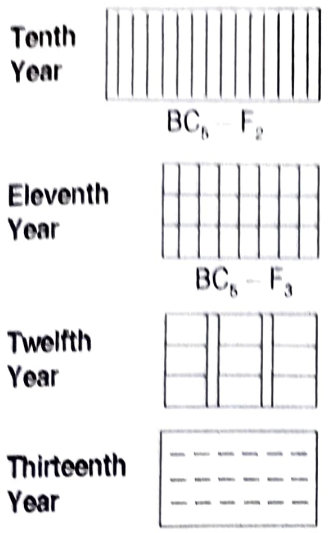
As in BC_1.

As in $BC_1 - F_2$.

As in BC_2.

No rust resistance test.

The plants are self pollinated to raise $BC_5 - F_2$ generation.



The plants are subjected to rust resistance test and selection is made on variety A.

The selfed seeds are harvested separately from the selected plants.

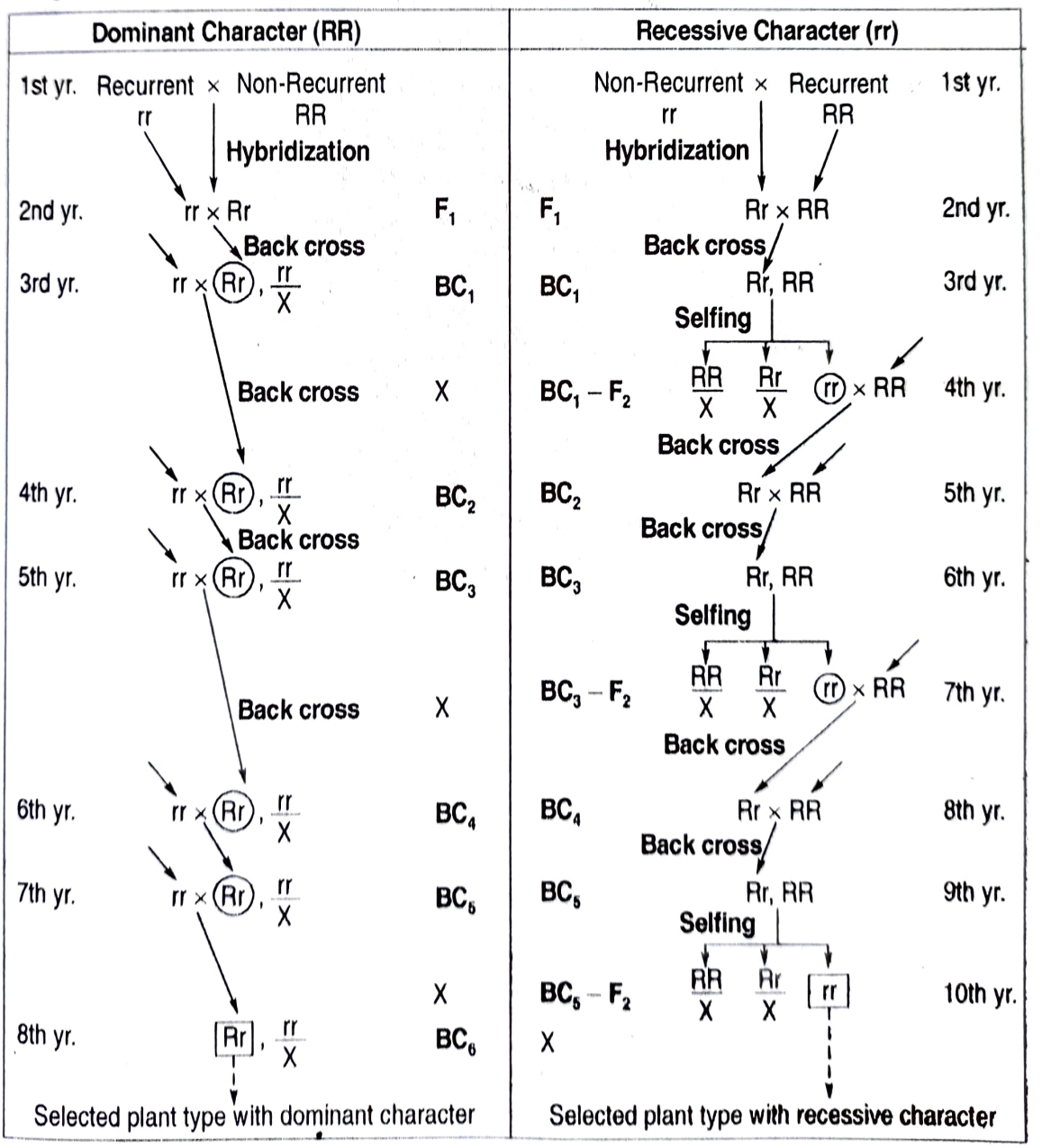
Individual plant progenies grown.

Progenies similar to variety A selected and composited.

Replicated yield trial alongwith variety A as check.

Seed multiplication and distribution to farmers.

Comparison between the transfer of dominant and recessive gene during back-cross method



(c) Transfer of quantitative character

Quantitative characters are governed by polygenes such as grain size, plant height, maturity time, etc. As during transfer intensity of characters will be lost, so the non-recurrent parent must have the characters more intense from than it is desired in the new variety. For transferring this type of character, each back-cross generation should be selfed and F_2 generation is grown which should have large population. Then the rigid selection is done for the character to be transferred. The system of alternate back-crossing and selfing goes on till the desired results are obtained. At the end of back-cross programme, F_2 is handled like pedigree method. The progenies which are more likely to recurrent parent bearing the desirable trait are selected and mixed to make up the new variety.

(d) Transfer of two or more characters in a single parent

For simultaneous transfer of many characters in a single back-crossing programme the characters from different non-recurrent parents are brought together by multiple crossing and then back-crossing to recurrent parent is performed. Larger back-cross progenies would be needed than in case of transfer of a single character, and also it may take long time as in each step all the desired characters may not get expressed.

The multiple characters can be transferred in a stepwise method. The recurrent parent is first improved for one character then it is used as recurrent parent for introduction of another new character. Thus in stepwise manner more than one characters can be introduced into a single recurrent parent.

Applications

Generally the back-cross method is used for transferring disease resistance characters to a good and well adapted variety. Other quantitative characters can also be transferred through back-cross method in both cross- and self-pollinated crop.

1. **Intervarietal transfer of simply inherited characters**: The characters like disease resistance, seed colour, plant height, etc., which are controlled by one or two major genes are most suited for transfer through back-cross method from one variety to another of the same species. The successful transfer depends on the minimum linkage between desirable and undesirable trait.
2. **Intervarietal transfer of quantitative characters**: Grain characters like seed size and shape, earliness, plant height–all can be transferred from one variety to another with the criteria of high heritability.
3. **Interspecific transfer of simply inherited characters**: Mainly the characters like disease resistance can be transferred from related species to cultivated species. This specially requires the relatedness between the species where the chromosomes can pair during meiosis. The transfer will be unsuccessful if the genetic environment of recurrent parent is not suitable for functioning of the

4. **Transfer of cytoplasm**: In case of transfer of male sterile character from one parent to another requires back-cross method. The variety or species from which the cytoplasm is to be transferred is used as female parent. The recurrent parent should be the male parent. After 6-8 back-crosses, the cytoplasm will be of the donor parent with the genotype of recurrent parent.
5. **Transgressive segregation**: Modification of back-cross method will produce transgressive segregants. Few (1 to 3) back-crosses with F_1 allow much heterozygosity to appear, or two or more recurrent parents may be used in back-cross programme to accumulate genes from them into the back-cross progeny. Such kind of modification would produce new variety which won't be like the recurrent parent.
6. **Production of isogenic lines**: Back-cross method is useful for production of isogenic lines, i.e., the lines of a crop which are identical in their genotype except for one gene. These isogenic lines are useful for studying the effect of individual genes.

Merits

1. This method does not change the genotype of the popular established variety, only it helps a single desirable character to be transferred in the existing variety.
2. As the recurrent parent is an established variety, so it is not necessary to test the yield performance which ultimately saves five years time, as well as expenses.
3. In case of short duration plant, 2-3 generations can be raised within a year as the selection is based on inheritance of a particular character, not on performance. So this method drastically reduces the time period required to develop a new variety.
4. Back-cross method requires smaller populations than the pedigree method.
5. Defects of an established variety can be removed using this method, may be only by introducing a single character.
6. Interspecific gene transfer only can be done through this method.
7. Transgressive segregation can be obtained in case of quantitative characters by modified back-cross method.
8. This method is very much useful for cytoplasmic gene transfer to the recurrent parent, i.e., new variety will bear the cytoplasm of donor parent and genotype of recurrent parent.

Demerits

1. The new variety is not superior in performance than the existing variety except the introduction of single character.
2. During transfer of such kind of single desirable gene, sometimes some undesirable genes may get transferred.

3. For introduction of more than one gene controlled character, multiple crossing programme is necessary which is often difficult, time taking and costly.
4. Once a recurrent parent taken in a back-cross method may get replaced by another superior variety of high yielding ability.

Achievements

Back-cross method is very much useful for transferring of simply heritable character like disease resistance to well adapted popular local variety.

In case of **wheat,** 'Kalyan Sona' is the popular established variety to which the leaf rust resistance character has been transferred from diverse sources like Robin, KI, Bluebird, Tobari, etc. using back-cross method.

In case of **Bajra,** Tift 23A, a male sterile line which was susceptible to downy mildew has made resistant through back-cross method.

For interspecific transfer of genes, back-cross method is widely used for crop improvement. Cultivated **sugarcane** (*Saccharum officinarum*) is susceptible to pests and disease, crossed with *S. spontanium* which is resistant. This brings resistance but with undesirable characters like more fibre, low sugar, thin stem, etc. By back-crossing with noble cane these undesired characters are removed.

In **cotton,** the hybridization between *Gossypium hirsutum* and *G. arboreum* yielded highly sterile F_1 hybrid, few tetraploid seeds were obtained. These plants were then back-crossed with *G. hirsutum* and two varieties have been selected from the back-cross progeny which are now being widely cultivated in Gujrat.

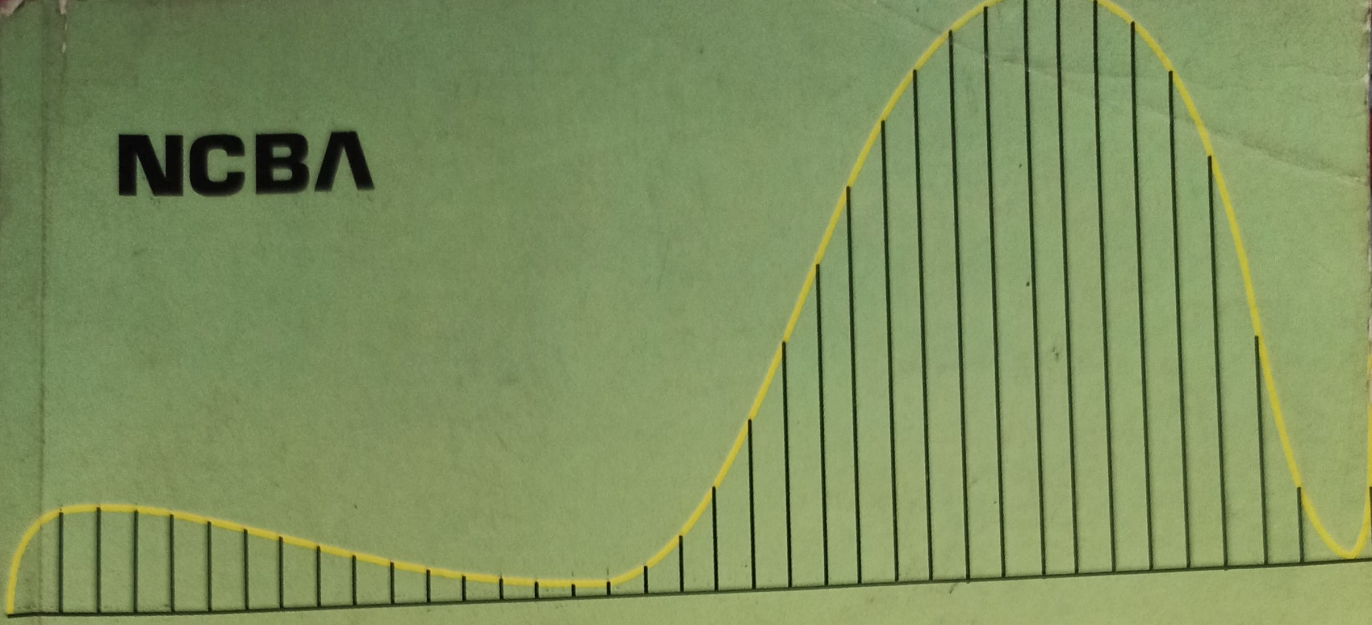
Except the characters of disease resistance other characters can also be transferred by the back-cross method. Such as in **cotton,** the ginning quality of fibre has been improved by back-cross method from the local variety. By using BD8 (wilt resistant, high spinning value but low ginning out turns) as recurrent parent and Goghari A26 (high ginning out turn) as non-recurrent parent, new variety **Vijay** was developed.

Comparison between Pedigree method and Back-cross method

Pedigree Method	Back-cross Method
1. The aim of this method to produce the new variety which is totally different from the parents bearing superior characters.	1. In this method the new variety is totally similar to recurrent parent except it bears a new character transferred from donor parent.
2. The method is used generally to improve the yield and other characters of the variety.	2. This method is used to improve the specific defect of a well adapted popular variety.
3. This method is useful to improve both qualitative and quantitative character.	3. This method is suitable for introducing a specific highly heritable character.

Pedigree Method	Back-cross Method
4. Gene transfer from related species is not suitable through this method.	4. It is the most suitable method for gene transfer from related species to produce addition or substitution lines.
5. Hybridization is limited only to produce the F_1 generation.	5. Hybridization with the recurrent parent is done in every back-cross generation.
6. F_1 and subsequent generations are allowed to self pollinate.	6. F_1 and subsequent generations are generally allowed to back-cross with recurrent parent.
7. F_2 and subsequent generations are much larger than those of the back-cross method.	7. The progeny of back-cross generations are smaller than pedigree method.
8. The method of breeding does not get modified whether the character is dominant or recessive gene controlled.	8. This method is different for transferring dominant and recessive gene controlled character.
9. The new variety is subjected to extensive testing and yield trial before releasing as new variety.	9. As the back-cross method always aims at improving some particular character of recurrent parent, so extensive yield test is not required before releasing as new variety.

NCBA



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Plant Breeding Biometry Biotechnology