PROCEDURES FOR BACKCROSSING

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Improvement of varieties which are carrying large numbers of desirable characters but are deficient in a few characters is accomplished by the backcross method of breeding. The locally accepted cultivated variety lacking a specific character was first crossed to a variety in which the required character was available. Then the F_1 of the above cross was backcrossed to the local variety. Subsequently the plants from the backcrossed progeny which were carrying the required character were selected and backcrossed 4 to 5 times to the local variety. The character in question was maintained in a heterozygous condition throughout this process. After recovering almost all the characters of the local variety in the backcrossed progeny during 5 to 6 backcrosses, the homozygote for the specific character was recovered by selfing and testing the final backcrossed progeny for homogeneity of the specific trait. The parent which was highly adapted and possessing many good characters but lacking a specific character was called an 'agronomic variety' or 'recurrent parent'. The parent from which the transfer of the required desirable character is contemplated is called a 'donor parent' or a 'non-recurrent parent'.

Genetic basis of backcrossin

If we visualize the progeny of the F_2 generation of a cross AA x aa it is expected to consist - ¼ AA : ½ Aa : ¼ aa. Although half of the progeny are homozygous in the segregating population, the desirable homozygous genotypic combination AA, will only be about ¼th of the total progeny. Instead of selfing the F_1, if it is backcrossed to the recurrent parent say AA, the segregation expectation is ½AA and ½Aa. Thus it is possible to recover half in the desired homozygous combination (AA). This type of expectation holds good for each and every gene pair by which the two parent differ. If additional backcrosses are made, the hybrid population can progressively be selected to be more like the recurrent parent.

Homozygosity is calculated in the followed manner

Proportion of homozygosity $= \frac{(2^m-1)^n}{2^m}$

where '$\underline{m}$' is number of generations of backcrossing plus the original cross

'n' is the number of gene pairs involved.

For instance the proportion of homozygosity that could be developed with a single pair of genes after 6th backcross is estimated as shown below :

$$\frac{(2^7-1)^1}{(2^7)} = \frac{127}{128} = 0.993 \text{ or } 99\%$$

The following three requirements need to be satisfied to achieve the desirable results in a backcrossing program.

1. A satisfactory recurrent parent must exist
2. It must be possible to retain a worthwhile intensity of the character under transfer through several backcrosses
3. Sufficient backcrosses must be made to reconstitute and recover the good qualities of the recurrent parent to a high degree.

With every backcross to the recurrent parent, the average proportion of germplasm from the donor parent is reduced to one-half. In the F_1 from the original cross, one half of its germplasm is from the donor parent and the proportion of it in the BC_1F_1 will be reduced to one quarter. Likewise the proportion of genes from the donor parent will be reduced gradually and the genes of the recurrent parent increased in the backcrossed progeny in the subsequent backcrosses.

The proportion of the genes of the donor parent in a backcrossed progeny is estimated to be $(\frac{1}{2})^n$; where '$\underline{n}$' is the number of backcrosses plus the original cross.

For instance after 6 backcrosses the proportion of genes of the donor parent in the backcrossed progeny are

$$(\tfrac{1}{2})^7 = \frac{1}{128} = 0.0078 \text{ or } 0.78\%$$

The proportion of genes of the agronomic variety in the 6th backcrossed progeny = 100 - 0.0078 = 0.99 or 99%.

<u>Number of backcrosses</u>

The number of recommended backcrosses varies from three to ten. Normally six backcrosses are carried out, in a breeding program by which time a reasonable proportion of genes (99.2%) of the recurrent parent are recoverable in the backcrossed progeny and then selfing is done to obtain an individual with the homozygous gene pair of the donor parent. This is achieved by growing progeny rows of the final backcross and testing these for homogenoity. Rows which are homogeneous (carrying the homozygous gene pair) are selected and advanced for yield tests.

<u>Transferring of the dominant gene from the donor parent to the agronomic variety:</u>

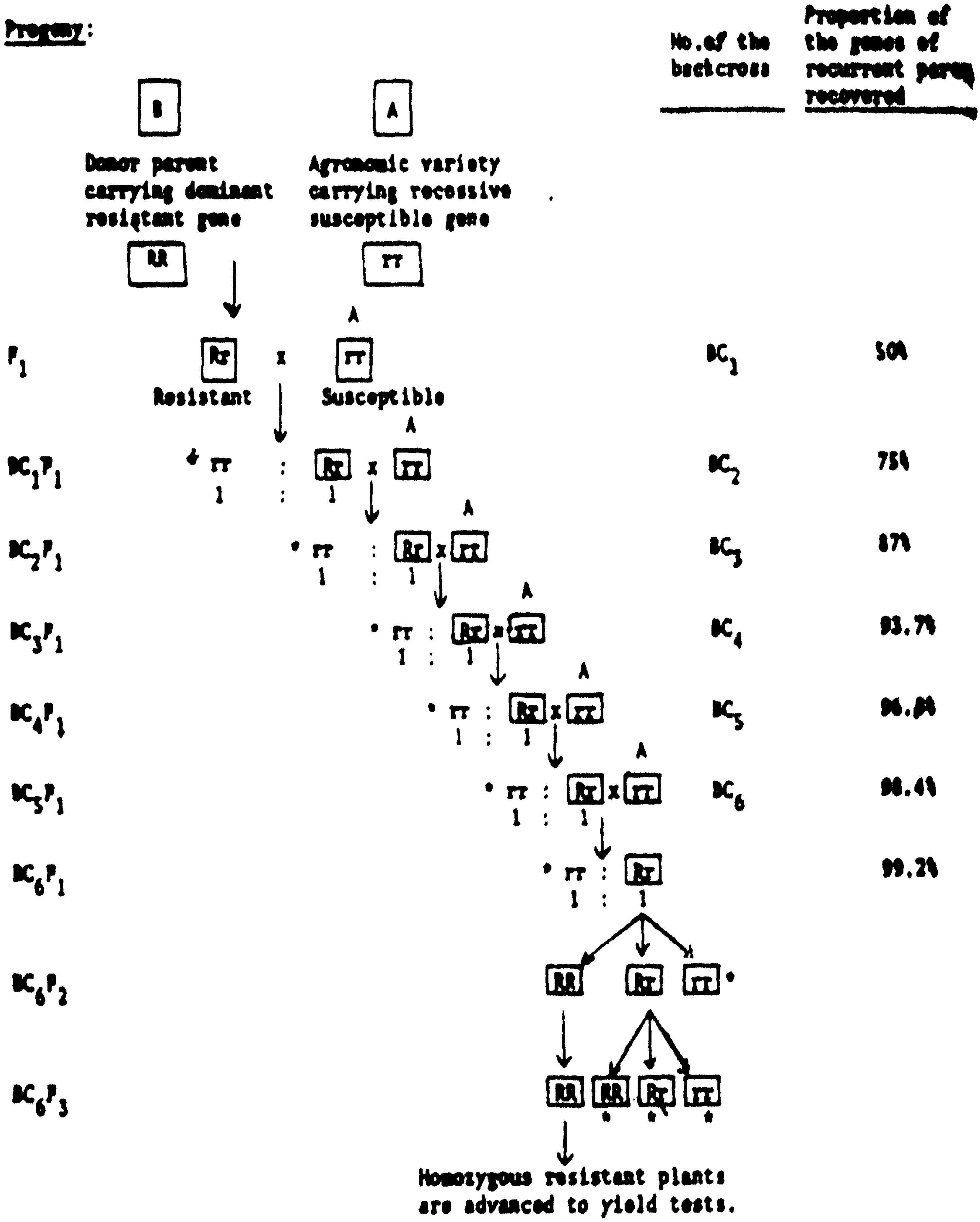
Transferring of a dominant gene pair from the donor parent to the agronomic variety is very easy. Initially a cross is made between the donor parent (RR) and the agronomic variety (rr) and the resulting

F_1 (Rr) is backcrossed to the agronomic variety (rr) carrying the recessive gene. The resulting backcrossed F_1 (BC_1F_1) will show two categories of plants, one showing resistance, carrying heterozygous dominant gene (Rr) and the other showing susceptibility carrying the homozygous recessive gene (rr). The susceptible plants are rejected and the resistant plant (Rr) is again backcrossed to the agronomic variety. Likewise the backcrossed F_1 progeny carrying the resistant gene is continuously backcrossed to the agronomic variety for six generations. At the end of the 6th backcross the backcrossed F_1 is raised and the resistant plants carrying heterozygous gene (Rr) are selected. The BC_6F_1 is then advanced to BC_6F_2 generations. This F_2 generation will segregate into resistant (RR and Rr) plants and susceptible (rr) plants. The selfed resistant plants (RR and Rr) are selected from the BC_6F_2 generation and the susceptible ones (rr) were discarded. Progeny rows of the selfed resistant plants are raised (BC_6F_3). Out of the resistant plants selected in BC_6F_2, those which carry heterozygous dominant genes (Rr) will again show segregation (RR, Rr, rr) for resistant and susceptible plants in the progeny rows of BC_6F_3, while the resistant plants with homozygous dominant gene (RR) exhibit homogeneity for the character of resistance without any segregation. The progeny rows showing uniformity for the character resistance are selected for further study. The selected resistant lines are tested for their yield performance in comparison with the agronomic variety. The lines showing consistently outstanding performance for yield are tested in multilocation tests and the superior entries are recommended for seed increase and release for cultivation by the growers.

The stepwise backcross program to transfer a pair of dominant genes (carrying resistance to a disease) from a donor parent to the agronomic variety is illustrated below.

In this backcross program the agronomic variety 'A' (recurrent parent) is susceptible to a disease and it is controlled by a pair of recessive genes (rr), while the donor parent 'B' (non recurrent parent) is resistant to the same disease and is controlled by a pair of dominant genes (RR).

Transferrin of dominant gene from the donor parent to the agronomic variety



* Plants showing susceptibility (with rr genes) are discarded in each backcrossed F_1 generation.

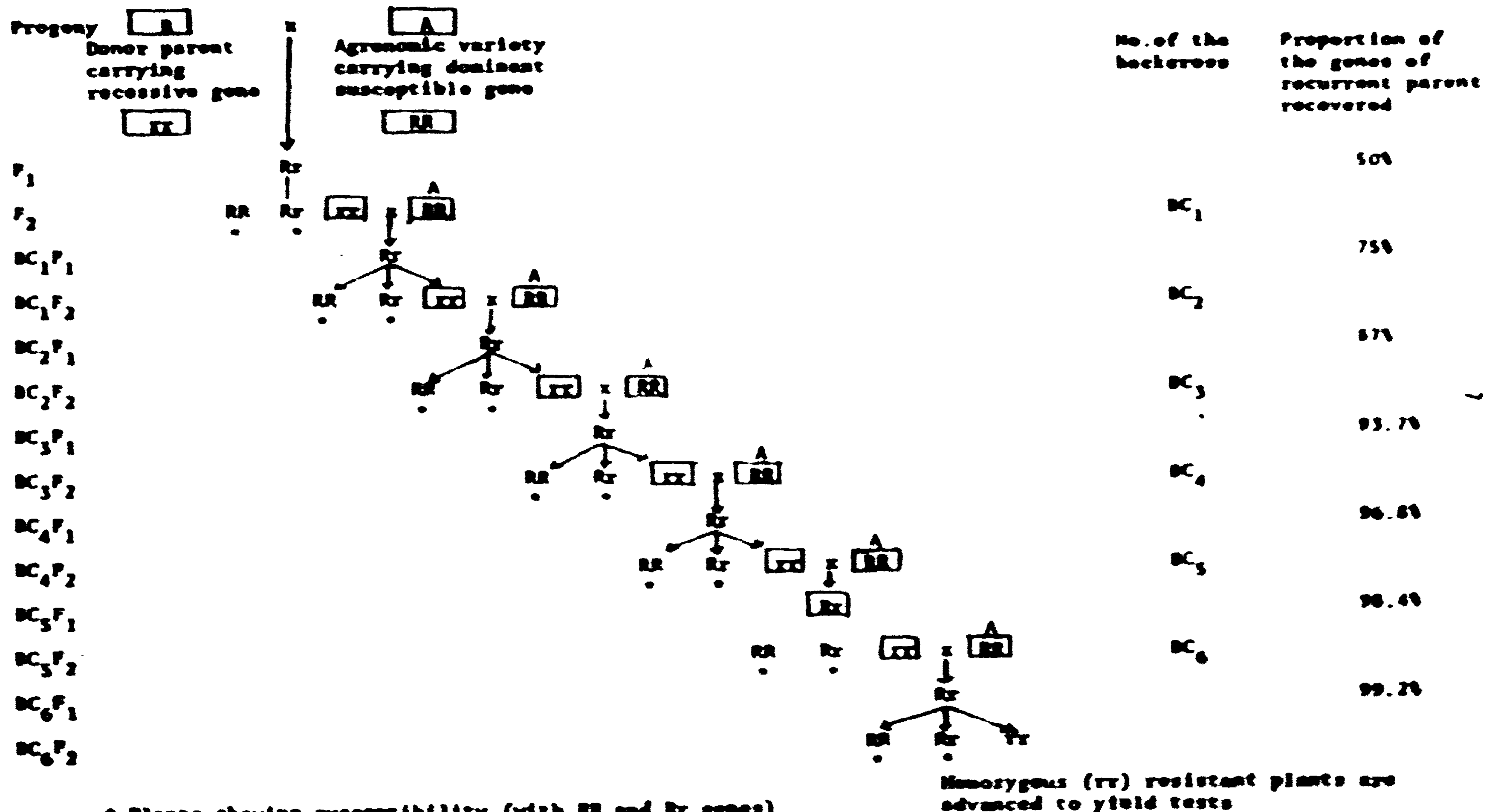
Transferring of recessive gene from the donor parent to the agronomic variety

When the character to be transferred is controlled by a recessive gene then there is a necessity to advance the F_1 generation to F_2 generation, so that the plant carrying the homozygous recessive gene can be picked up from the segregating population and subsequently backcrossed. Therefore, backcrossing and testing the backcrossed F_2 generation are carried out alternately in this system.

After the sixth backcross, the backcrossed F_1 (BC_6F_1) will be recovering almost all the desirable genes (99.2%) of the agronomic variety or recurrent parent, while also carrying the pair of genes of the donor parent for the character of resistance in a heterozygous (Rr) condition. Then the BC_6F_1 is advanced and is raised in BC_6F_2 generation. BC_6F_2 generations shows segregation for susceptible plants (RR, Rr) and resistant plants (rr). The resistant plants are selected and tested for their yield performance in comparison with the agronomic variety. The lines showing consistantly outstanding performance for yield are tested in multilocation tests and the superior entries are recommended for their release for cultivation by the growers.

The process of transferring the disease resistance controlled by a pair of recessive genes from a donor parent to an agronomic variety which is susceptible for the disease is illustrated below.

Transferring of recessive gene from the donor parent to the agronomic variety



* Plants showing susceptibility (with RR and Rr genes) are discarded in each backcross F_2 generation.

Transferring a quantitative character

A quantitative character is controlled by several genes and it is difficult to identify the required plant in the F_2 generation. So when a quantitative character is to be transferred the progeny is advanced to atleast the F_3 generation to be able to select the plant carrying the desirable character and then the selected plant is backcrossed with the agronomic variety. Thus advancing the progeny to the F_3 generation and backcrossing are alternated in this situation. Final selection is usually carried out after the 6th backcross. When the character in question is controlled by a large number of genes and the character is associated with low heritability, it is necessary to raise a large number of plants in the F_2 and F_3 generation in order to recover the plant with the desirable combination character and proceed with further backcrossing. The process of transferring a quantitative trait is illustrated below.

Transferring of the quantitative character from the donor parent to the Agronomic variety

B (Donor parent carrying the genes for the expression of a desirable quantitative trait.) x A (Agronomic variety lacking the quantitative trait.)

F_1 ↓ F_2 ↓ F_3 (selected plant) x (A) .. .. BC_1

BC_1F_1 ↓ BC_1F_2 ↓ BC_1F_3 (selected plant) x (A) .. .. BC_2

BC_2F_1 ↓ BC_2F_2 ↓ BC_2F_3 (selected plant) x (A) .. .. .. BC_3

BC_3F_1 ↓ BC_3F_2 ↓ BC_3F_3 (selected plant) x (A) .. .. BC_4

BC_4F_1 ↓ BC_4F_2 ↓ BC_4F_3 (selected plant) x (A) .. BC_5

BC_5F_1 ↓ BC_5F_2 ↓ BC_5F_3 (selected plant) x (A) BC_6

BC_6F_1 ↓ BC_6F_2 ↓ BC_6F_3 (Desirable plant selected and advanced to yield test)

Transferrin of more than one character :

When two desirable characters are available in a donor parent and when it is contemplated to transfer these two characters to the agronomic variety which is lacking those characters, it is always desirable to transfer initially only one character out of the two to the agronomic variety using the backcross method. After the first backcross program is completed, the desired improved line possessing the first desirable character is selected. The line having that single desirable character is treated as the agronomic variety and then it is further crossed to the donor parent in order to transfer the other desirable character. The progeny is subsequently backcrossed to the agronomic variety and the second character also is recovered.

Briggs made an attempt and succeeded in transferring two desirable characters which were available in a donor parent to an otherwise accepted agronomic variety of wheat. He transferred the characters one after the other to the agronomic variety. The variety of wheat - 'Big club' was resistant to the incidence of 'Hessainfly', but was susceptible to the two diseases - 'Bunt' and 'Stem rust'. He identified the donor parent'Baart 38' which was resistant to both 'Bunt' and 'Stem rust' and decided to transfer those two characters to the variety 'Big club'. To start with he crossed the 'Big club' (agronomic variety) to 'Baart 38' (donor parent). The resulting F_1 was backcrossed to the agronomic variety and in the subsequent backcrosses, selection was directed towards only one character - 'Bunt' resistance. Thus at the end of the first backcross program a line which was resembling 'Big club' and showing resistances for 'Hessain fly' and 'Bunt' could be developed. This improved line was chosen as the agronomic variety and was crossed again to 'Baart 38' in order to transfer the other character 'resistance to Stem rust'. During the process of this second backcrossing, selection was exercised for 'Stem rust resistance'. At the end of the second back cross program a line, which was resembling the variety 'Big club' and possessing the resistances for 'Hessain fl/', 'Bunt' and 'Stem rust' could be developed. That variety was named as 'Big club 53'. The process of backcrossing which was carried out in two steps is illustrated below :

Baart 38 x Big club

Baart 38	Big club
donor parent	recurrent parent
resistant to 'Bunt'	(agronomic variety)
resistant to 'Stem' rust'	resistant to 'Hessain fly'
	susceptible to 'Bunt'
	susceptible to 'Stem rust'
First backcross program	Transferred 'Bunt' resistant to Big club

↓

Baart 38 x Big club

Baart 38	Big club
donor parent	recurrent parent
resistant to 'Bunt'	(agronomic variety)
resistant to 'Stem rust'	resistant to 'Hessain fly'
	resistant to 'Bunt'
	Susceptible to 'Stem rust'
Second back cross program	Transferred 'Stem rust' resistant to Big club

↓

'Big club 53'
resistant to 'Hessain fly'
resistant to 'Bunt'
resistant to 'Stem rust'

Heritability :

It is important that the character under transfer is having high heritability, because selection for the character under transfer has to be made through several rounds of backcrossing. As for the characters of the recurrent parent they are taken care of automatically by the backcrossing procedure itself with the result that the breeder need pay little or no attention towards them. The character under transfer need to be identified readily in the hybrid populations. Characters which are governed by a single pair genes and associated with high heritability are the easiest to handle. A character of high heritability governed by several genes might well be more easily transferred by backcrossing than a character of low heritability governed by fewer genes.