UNIVERSITEIT GENT

FACULTY OF **BIOSCIENCE ENGINEERING**

Plant Breeding

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Backcross breeding

A backcross is a cross between a F_1 and one of its parents.

There are *single backcrosses* and *repeated backcrosses.*

A F_2 population, born from a segregation of a F_1 holds 3^n (n=number of different loci) genotypes. The same F_1 backcrossed to one of its homozygous parents holds 2^n genotypes. Hence a backcross decreases drastically the number of genotypes, theoretically facilitating the discovery or detection of the wanted genotype.

Backcross breeding

The offspring of a backcross statistically holds 75% of the genes of the backcross parent ([1-(1/2)^m] ; m is number of backcross generations).

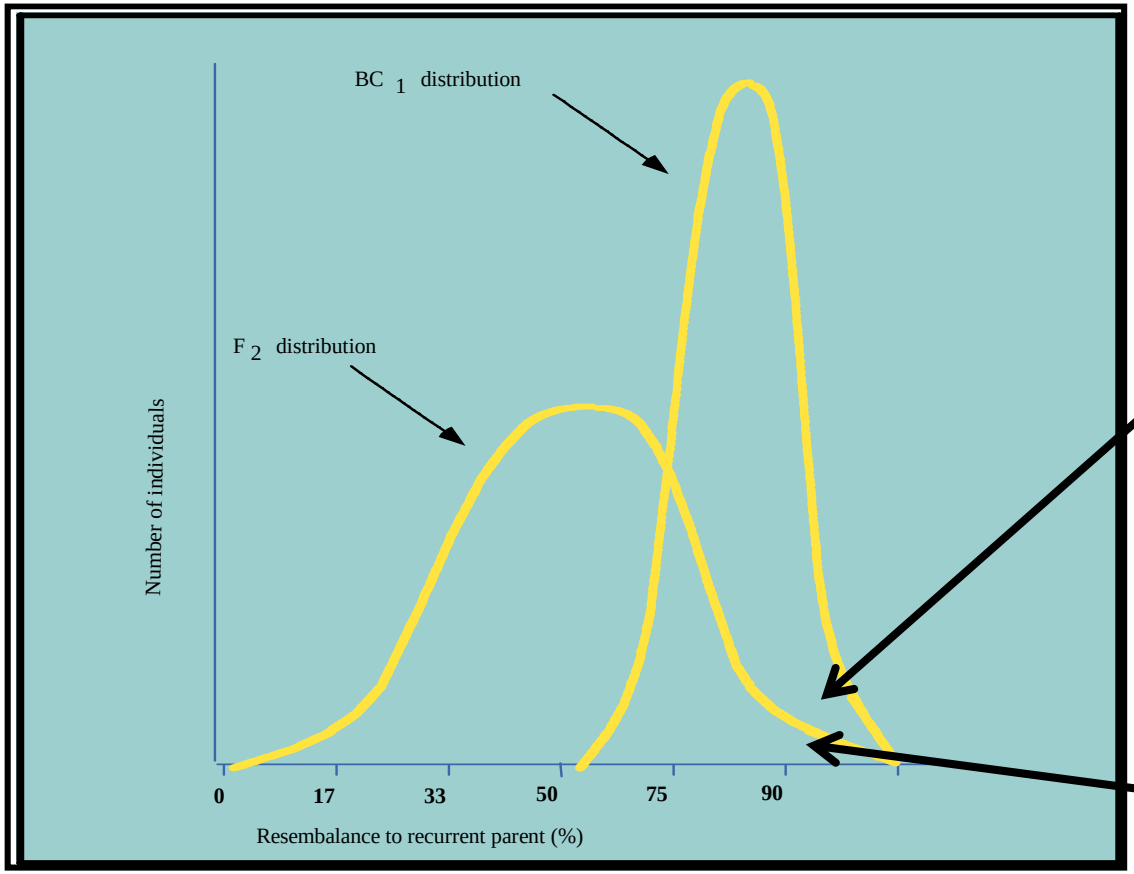
Is this true for each individual in this offspring ?

Repeated backcrosses to the same ***recurrent parent*** **(P_r)** expulse gradually the genes of the ***donor parent*** **(P_d).**

Backcross breeding

Critical success factors in backcrossing are :

- One needs an excellent P_r : an elite line, elite inbred line, elite variety.
- The genotype of P_r should be recovered after a reasonable number of backcrosses.
- The traits of interest in P_d should have a high heritability. A monogenic trait with a low heritability is difficult to work with; on the other hand a quantitative trait may be easy to introgress if its heritability is high, even if the number of genes concerned is high or not known.

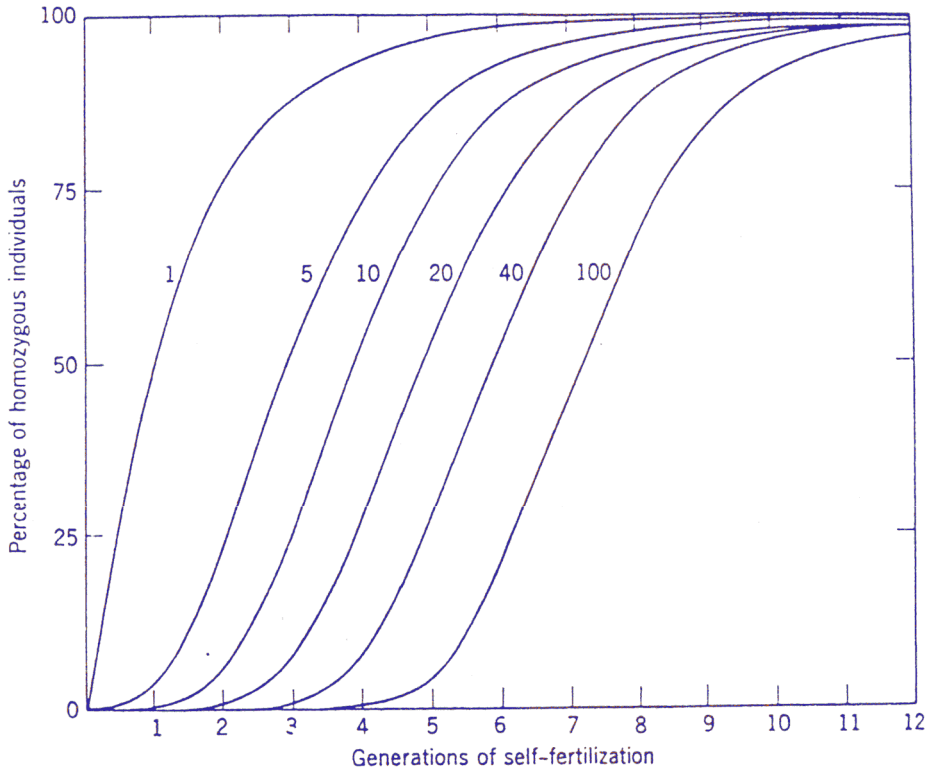


BC1:15%>90%RCP

F2: 3%>90%RCP

Backcross breeding

- **The degree of homozygosity** in a certain generation equals $(2^m-1)/2^m$, m = number of backcrosses.
- **The number of homozygous individuals** equals $[(2^m-1)/2^m]^x$; x being the number of heterozygous loci in F_1.
- *Convince yourself that the number of homozygous individuals becomes quite high after 3-4 backcrosses in case the number of segregating loci is limited.*


100
75
50
25
0
Percentage of homozygous individuals
1
5
10
20
40
100
1
2
3
4
5
6
7
8
9
10
11
12
Generations of self-fertilization

P1 (BB) x P2 (bb)

↓

F1 (Bb) x P1 (BB)

↓

BC1	BB	Bb
	1/2	½
genotypic value		
	+a	d

Mean = 1/2a +1/2d

Variance = $1/4a^2 + 1/4d^2 - 1/2ad$ if d=0

↙

Variance of BC is 1/2 that of F2

Table 28-1 Total Number of Plants Needed to Obtain Required Number with Desired Genes

		r (Number of Plants to Be Recovered)								
*p**	*q*†	1	2	3	4	5	6	8	10	15
0.95	$\frac{1}{2}$	5	8	11	13	16	18	23	28	40
	$\frac{1}{3}$	8	13	17	21	25	29	37	44	62
	$\frac{1}{4}$	11	18	23	29	34	40	50	60	84
	$\frac{1}{8}$	23	37	49	60	71	82	103	123	172
	$\frac{1}{16}$	47	75	99	122	144	166	208	248	347
	$\frac{1}{32}$	95	150	200	246	291	334	418	500	697
	$\frac{1}{64}$	191	302	401	494	584	671	839	1002	1397
0.99	$\frac{1}{2}$	7	11	14	17	19	22	27	32	45
	$\frac{1}{3}$	12	17	22	27	31	35	44	52	71
	$\frac{1}{4}$	17	24	31	37	43	49	60	70	96
	$\frac{1}{8}$	35	51	64	77	89	101	124	146	198
	$\frac{1}{16}$	72	104	132	158	182	206	252	296	402
	$\frac{1}{32}$	146	210	266	218	268	316	508	597	809
	$\frac{1}{64}$	293	423	535	640	739	835	1020	1198	1623

*p = probability of recovering r plants with the desired genes.

†q = frequency of plants with desired genes.

Source: Sedcole, 1977.

Advantages of BC

- **Provides breeder a high degree of control**
- **It is repeatable**
- **Extensive field trials are not required**
- **Few notes (record keeping)**

Disadvantages of BC

- **Improved variety is same as recurrent parent except for trait transferred**
- **Minimal recombination**
- **Linkages to deleterious genes**

Marker-assisted backcrossing (MABC)

one does not have to wait for phenotypic expression of traits

It has the potential to improve the reliability of the selection process
On top of an improvement of the reliability, the breeding goal might be achieved with less backcrosses, i.e. faster.

P_d : *aabb**CC**ddEEFF*…… x *AABB**cc**ddEEff*….. **P_r**

gametes *:* *ab**C**dEF* *AB**c**dEf*

F_1 : *AaBb**Cc**ddEEFf*……

Gametes made from F_1 individuals: among many different gametes, *AB**C**dEf* may occur: it is nearly isogenic to the P_r gametes - with the exception of the wanted allele ***C.***

From B_1F_1 (=BC1) on, one is looking for plants with a genotype as close as possible to the genotype of the recurrent parent, with the exception of the donor gene(s).

This means : one is looking for plants with the highest possible degree of homozygosity of the recurrent genome, with the exception of the donor gene(s).

Bt-maize

Ragot *et al*. 1995

Ragot *et al*., 1995

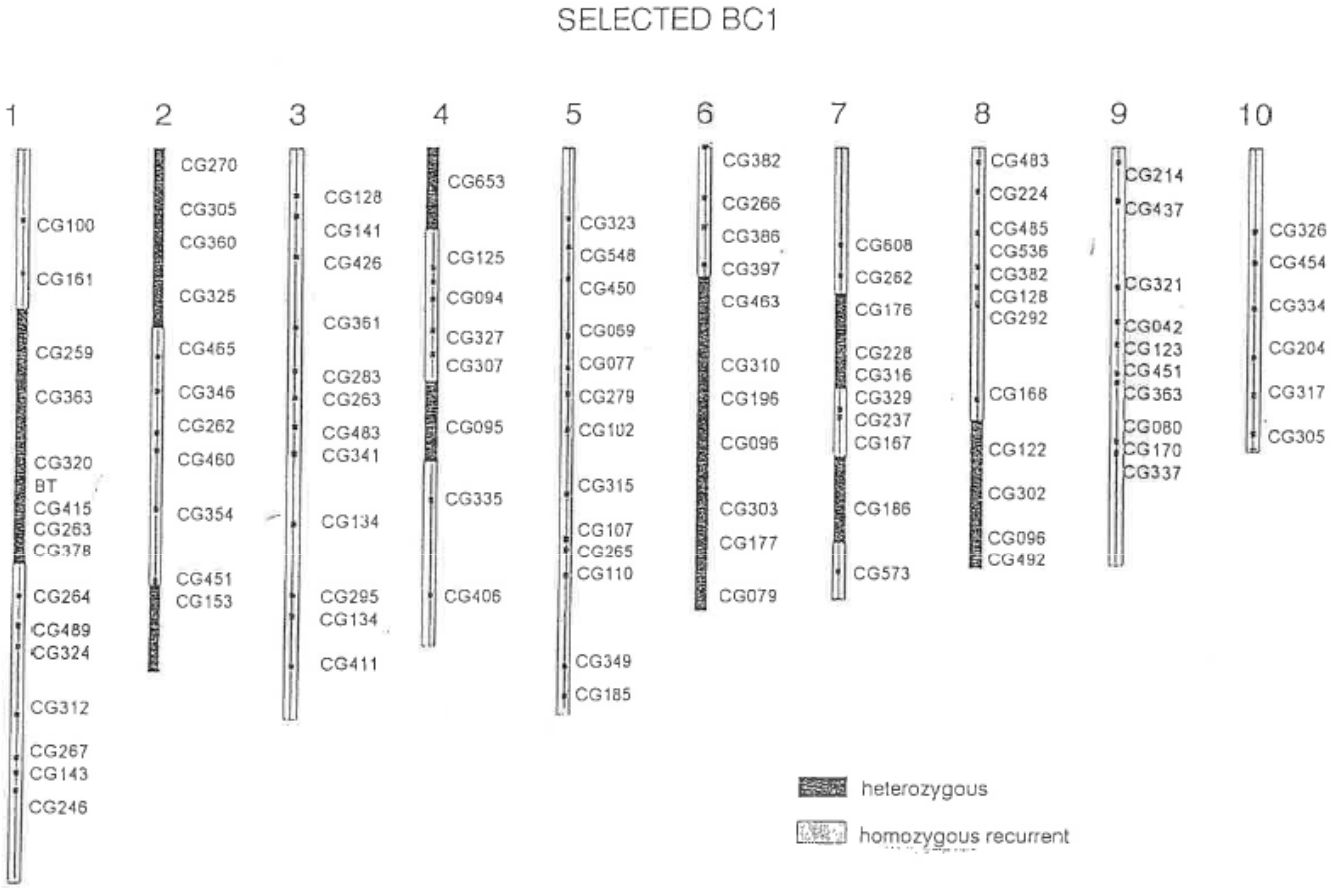


Figure 1-a: Genetic maps of the backcross-derived individuals selected in the first four generations of a marker-assisted backcross program. The locus to be introgressed (*Bt*) is located on chromosome 1.

Ragot *et al*., 1995

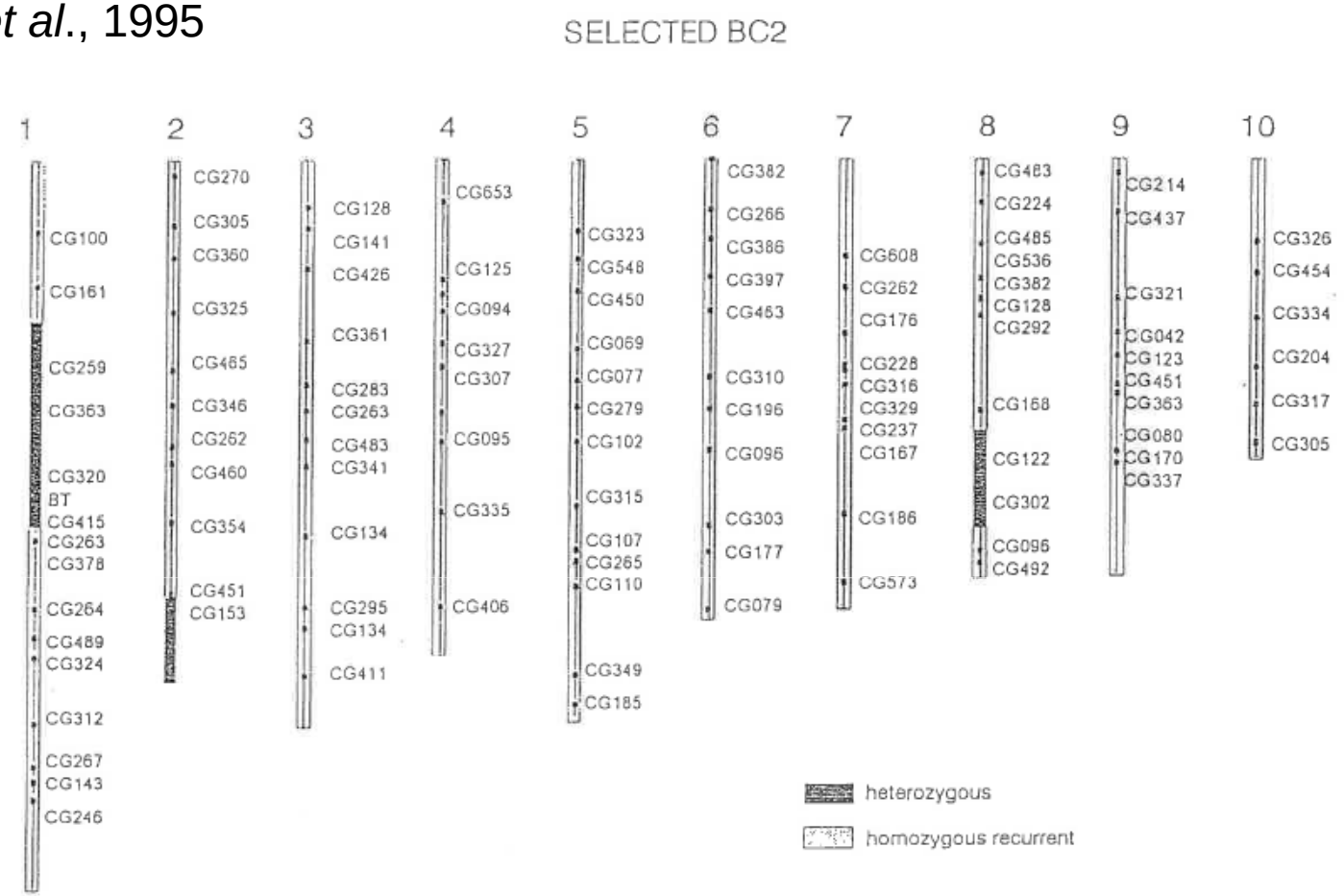
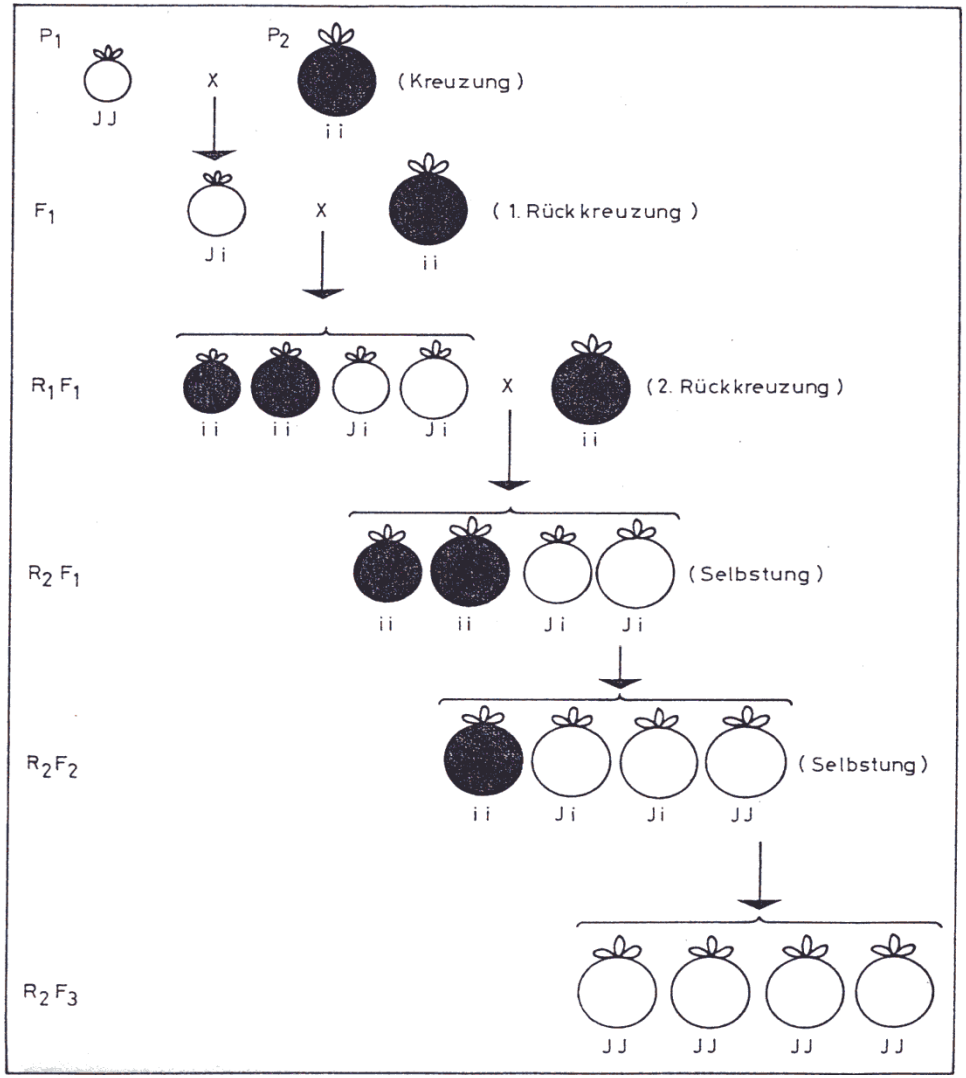


Figure 1-b: Genetic maps of the backcross-derived individuals selected in the first four generations of a marker-assisted backcross program. The locus to be introgressed (*Br*) is located on chromosome 1.

Table 1: Proportion and characteristics of plants carrying the genes of interest, in the first four generations of a marker-assisted backcross program.

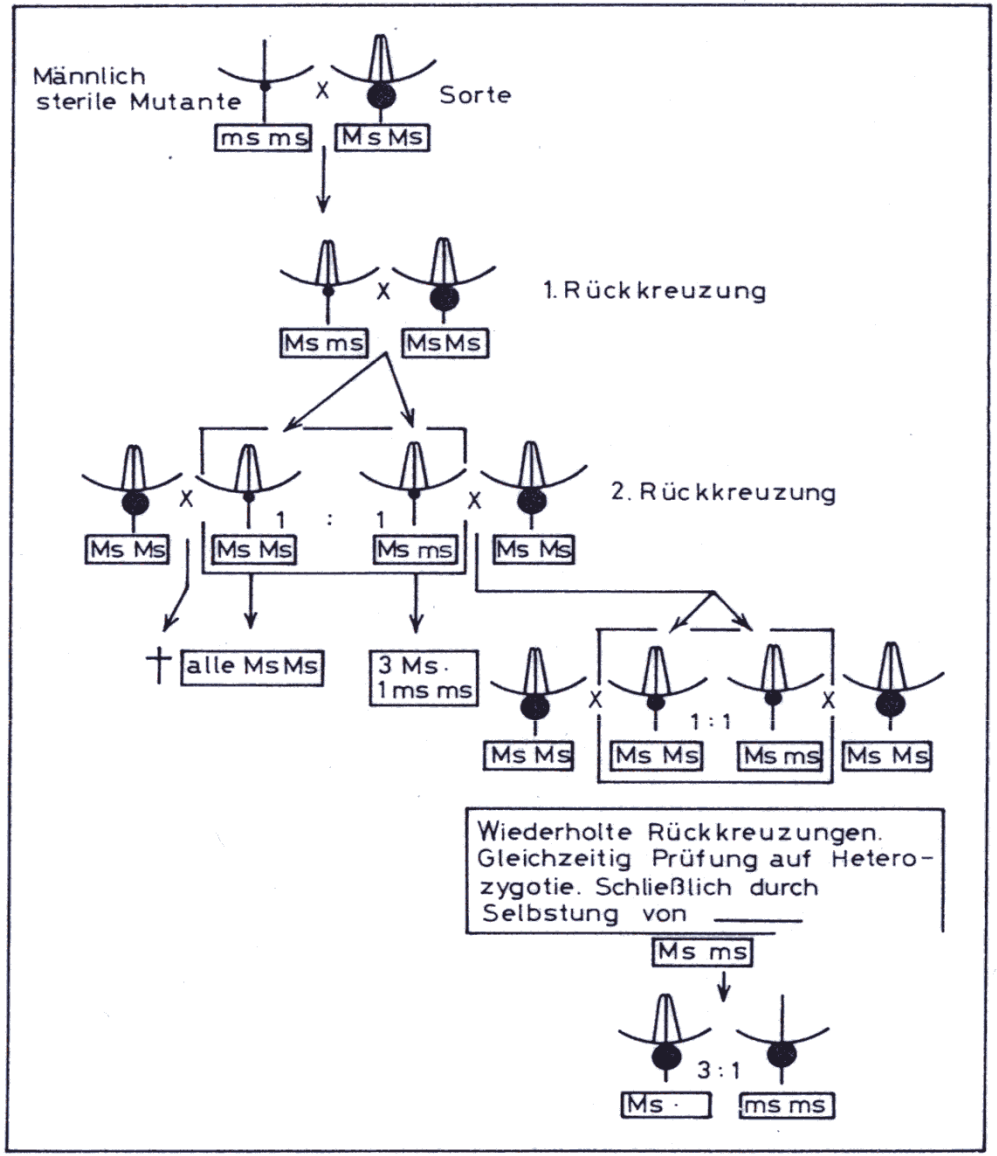
generation	% phosphinothricin resistant plants	RFLP genotyping			nb plants analyzed *	% homozygous recurrent parent genotype				nb heterozygous chromosome segments ***			
		nb plants	nb loci	nb datapoints		mean	std dev	5-best mean **	selected plant	mean	std dev	5-best mean **	selected plant
BC1	49.05	96	61	5856	87	48.72	10.35	68.31	70.45	11.01	2.17	7.75	6
BC2	44.65	61	22	1342	30	83.42	5.64	91.98	90.84	5.03	1.54	3.20	3
BC3	46.32	72	10	720	71	93.83	1.85	96.82	98.03	2.20	0.71	1.60	1
BC4	-	26	3	78	26	98.23	0.49	99.09	99.36	1.00	0.00	1.00	1

* Plants for which two or more adjacent markers had missing values were not included in the analyses
** Mean value of the five individuals having the five highest percentages of homozygous recurrent parent genotype.
*** Including the segment carrying the transgene construct.

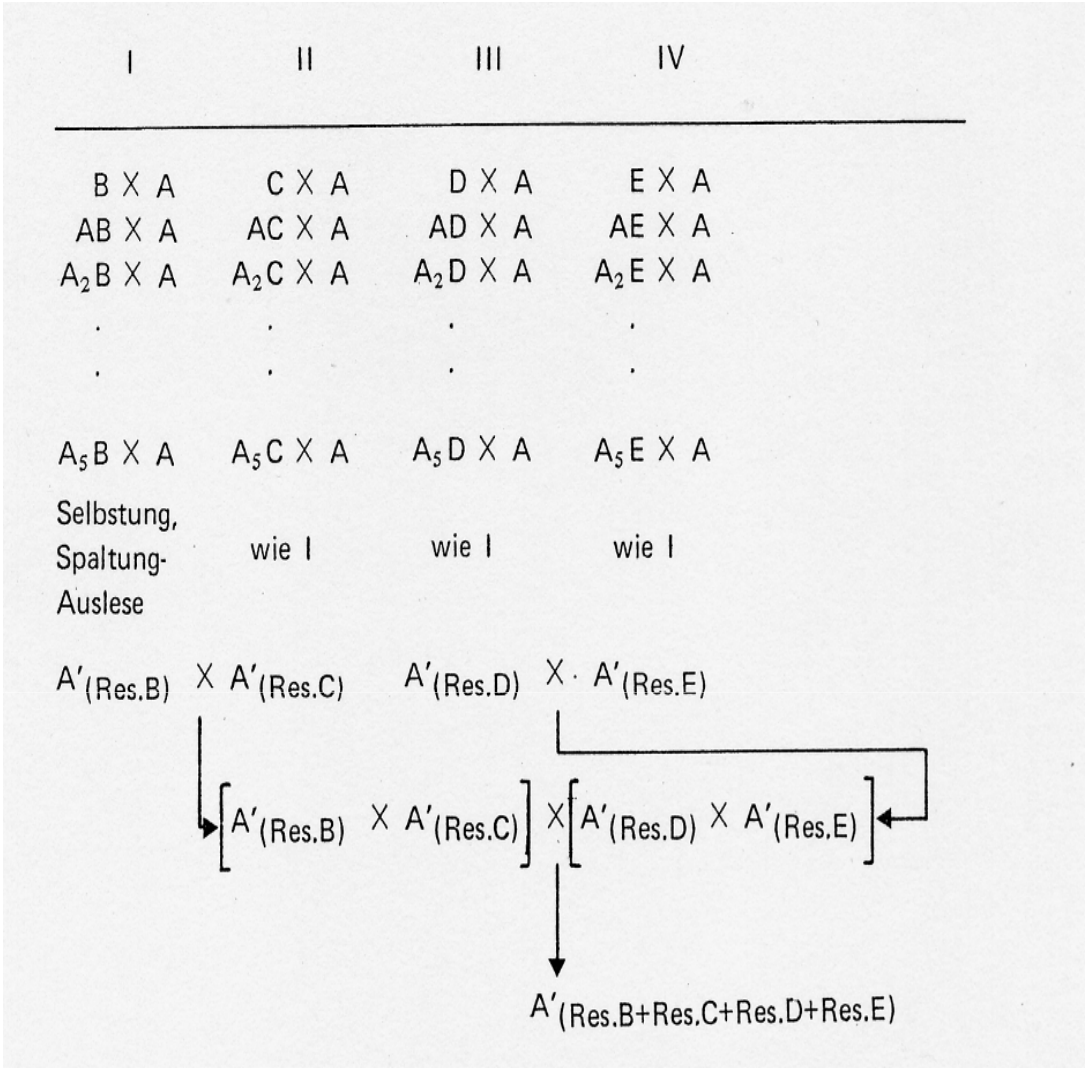


Repeated backcrossing to introgress *Cladosporium fulvum* resistance (dominant) from *Lycopersicon pimpinellifolium* (small tomatoes) in *Lycopersicon esculentum* (large tomatoes). Kuckuck, 1979.

Help of markers



Repeated backcrossing to bring nuclear male sterility (recessive) in an elite line. Kuckuck, 1979.



Stepwise backcrossing to bring different traits in one elite parent (today we call this stacked traits): the backcrossings start at the same moment. Hoffmann et al., 1971.

Help of markers !!!!!

Backcross inbred lines (BIL's)

- *Lycopersicon esculentum* x *L pennellii* (small, green, sweet fruits) + a number of BC's with L. esculentum, followed by self-fertilization: result: BIL's

↓

- Ideally : a number of homozygous lines, each containing a different piece of *pennellii* DNA on different chromosomal sections.
- Correlation between phenotypical performances genotype.

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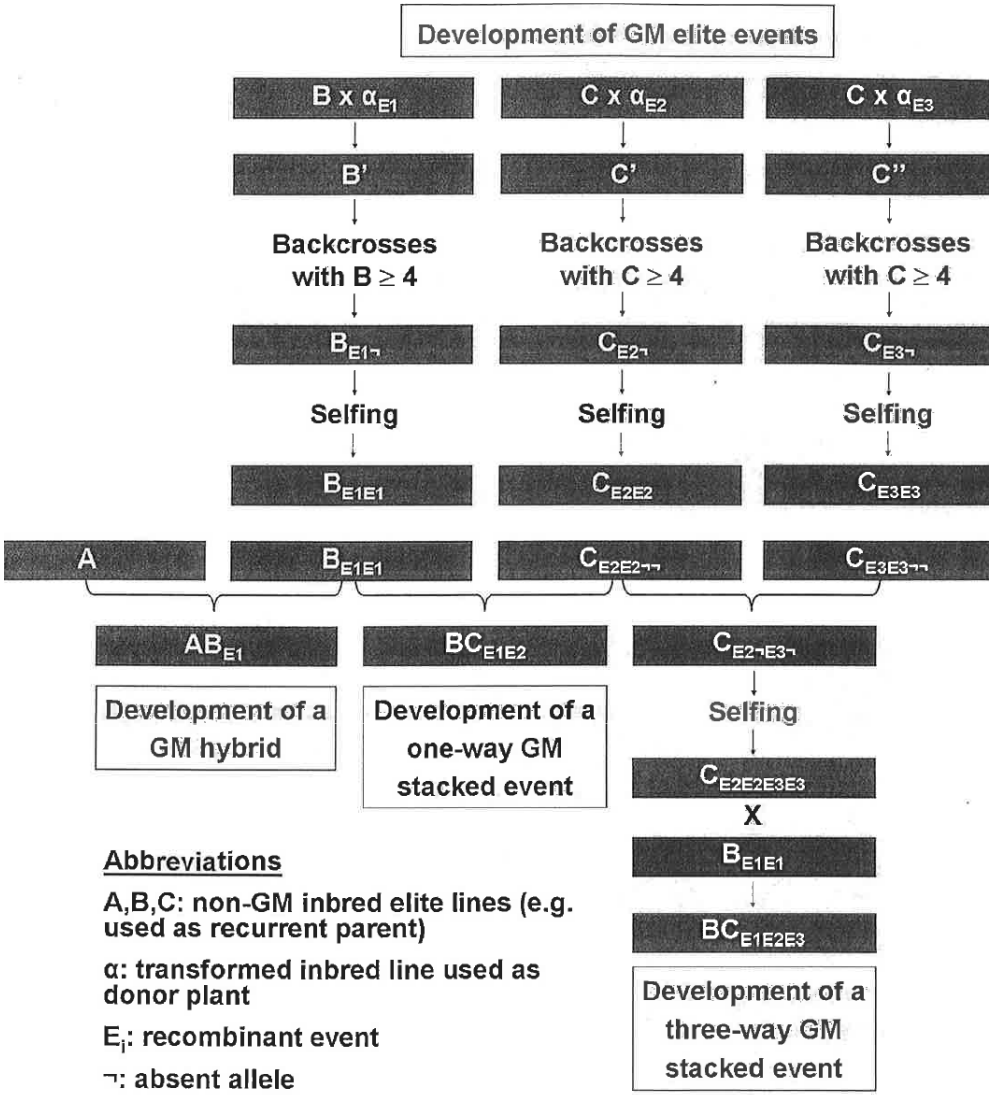
- Identification of some specific regions of *pennelli* DNA responsible for specific performances

Different transgenic events stacked in elite plants

Crossing scheme


Development of GM elite events
B x α_{E1}
C x α_{E2}
C x α_{E3}
B'
C'
C''
Backcrosses with B ≥ 4
Backcrosses with C ≥ 4
Backcrosses with C ≥ 4
$B_{E1\neg}$
$C_{E2\neg}$
$C_{E3\neg}$
Selfing
Selfing
Selfing
B_{E1E1}
C_{E2E2}
C_{E3E3}
A
B_{E1E1}
$C_{E2E2\neg\neg}$
$C_{E3E3\neg\neg}$
AB_{E1}
BC_{E1E2}
$C_{E2\neg E3\neg}$
Development of a GM hybrid
Development of a one-way GM stacked event
Selfing
$C_{E2E2E3E3}$
X
B_{E1E1}
BC_{E1E2E3}
Development of a three-way GM stacked event
Abbreviations
A,B,C: non-GM inbred elite lines (e.g. used as recurrent parent)
α: transformed inbred line used as donor plant
E_i: recombinant event
¬: absent allele