Breeding
Self Pollinated Crops

Cultivars

- **Cultivar**

  Is a group of genetically similar plants, which may be identified (by some means) from other groups of genetically similar plants

- **Essential Characteristics:**
  - **Identity: cultivar must be distinguishable from other cultivars**
  - **Reproducibility: the distinguishing characteristic(s) need to be reproduced in the progeny faithfully**

Types of Cultivars

Open-Pollinated cultivars

- O.P. seeds are a result of either natural or human selection for specific traits which are then reselected in every crop.

- The seed is kept true to type through selection and isolation; the flowers of open-pollinated or O.P. seed varieties are pollinated by bees or wind.

Types of Cultivars

Synthetic cultivars

- A population developed by inter-crossing a set of good combiner inbred lines with subsequent maintenance through open-pollination.

- The components of synthetics are inbreds or clones so the cultivar can be periodically reconstituted.

Types of Cultivars

- **Multi-line cultivars**

  A mixture of isolines each of which is different for a single gene controlling different forms of the same character (e.g., for different races of pathogens)

- **F1 cultivars**

  The first generation of offspring from a cross of genetically different plants

- **Pure-line cultivars**

  The progeny of a single homozygous individual produced through self-pollination

Cultivars and Self-pollinated Crops

In self-pollinated species:

- Homozygous loci will remain homozygous following self-pollination
- Heterozygous loci will segregate producing half homozygous progeny and half heterozygous progeny
- Plants selected from mixed populations after 5-8 self generations will normally have reached a practical level of homozygosity

Cultivars and Self-pollinated Crops

- **In general, a mixed population of self-pollinated plants is composed of plants with different homozygous genotypes (i.e., a heterogeneous population of homozygotes**

- **If single plants are selected from this population and seed increased, each plant will produce a 'pure' population, but each population will be different, based on the parental selection**

Breeding Self-pollinated Crops

- Selection involves the ID and propagation of individual genotypes from a land race population, or following designed hybridizations

- Genetic variation must be identified and distinguished from environment-based variation

- Selection procedures practiced in mixed populations of self-pollinated crops can be divided into two selection procedures

Breeding Methods of Self Pollinated Crops

1. Pure line
2. Mass
3. Bulk
4. Pedigree
5. Single Seed Descent (modified pedigree)
6. Backcross

Pure Line

Pure Line: (Recount Johannsen. 1903)

- usually no hybridization
- Initial parents (IPs) selected from a heterogenous population (i.e. genetically variable)
- procedure continues until homogeneity is achieved
- last phase is field testing

Pure-line Selection

- A pure line consists of progeny descended solely by self-pollination from a single homozygous plant

- Pure line selection is therefore a procedure for isolating pure line(s) from a mixed population

Pure-line Selection

- Pure line cultivars are more uniform than cultivars developed through mass selection (by definition, a pure line cultivar will be composed of plants with a single genotype)

- Progeny testing is an essential component of pure line selection

- Improvement using pure line breeding is limited to the isolation of the 'best' genotypes present in the mixed population

Pure-line Selection

- **More effective than MS in development of self-pollinated cultivars**
- **However, leads to rapid depletion of genetic variation**
- **Genetic variability can be managed through directed cross hybridizations**
- **Essential to progeny test selections**

Pure-line Selection-Steps

- **Select desirable plants**
  - **Number depends on variation of original population, space and resources for following year progeny tests**
  - **Selecting too few plants may risk losing superior genetic variation**
  - **A genotype missed early is lost forever**
- **Seed from each selection is harvested individually**

Pure-line Selection-Steps

- **Single plant progeny rows grown out**
  - **Evaluate for desirable traits and uniformity**
  - **Should use severe selection criteria (rogue out all poor, unpromising and variable progenies)**

- **Selected progenies are harvested individually**

- **In subsequent years, run replicated yield trials with selection of highest yielding plants**

- **After 4-6 rounds, highest yielding plant is put forward as a new cultivar**

Advantages

1. ID of best pure line reflects maximum genetic advance from a variable population; no 'poor' plants maintained

2. Higher degree of uniformity

3. Selection based on progeny performance is effective for characters with relatively low h^2

Disadvantages

1. **Requires relatively more time, space, and resources for progeny testing than MS to develop new cultivar**

2. **High degree of genetic uniformity; more genetically vulnerable and less adaptable to fluctuating environments**

3. **ID and multiplication of one outstanding pure-line depletes available genetic variation; leads to fast genetic erosion**

How long will a cultivar remain pure?

1. As long as the commercial life of the cultivar, unless:
   - Seed becomes contaminated with seed from other sources (e.g. from harvesting and seed cleaning equipment)
   - Natural out-crossing occurs (amount varies by species but seldom exceeds 1-2% in self-pollinated crops)
   - Mutations occur
2. To maintain purity, off-types arising from mutation or out-crossing must be rogued out

Mass Selection

Mass Selection

- May or may not include hybridization
- Make IP selections based on single, ideal or desirable phenotype and BULK seed
- May repeat or go directly to performance testing

Mass Selection has 2 important functions:

1. Rapid improvement in land-race or mixed cultivars
2. Maintenance of existing cultivars (sometimes purification)

* Many pb'ers of self pollinated crops believe that combining closely related pure lines imparts "genetic flexibility" or buffering capacity and so are careful to eliminate only obvious off types

- **Success depends on extent of variation and h^2 of the traits of interest**

- **Land races make an ideal starting source**
  - **High genetic variability accumulated over generations of mutation and natural hybridization**

Mass Selection

Initial selection

- Can be either a positive or a negative selection
- Negative screening: A screening technique designed to identify and eliminate the least desirable plants.
- positive screening: which involves identifying and preserving the most desirable plants.

Mass Selection - 1st Year

- Select plants with respect to height, maturity, grain size, and any other traits that have ‘production’ or ‘acceptability’ issues

- Bulk seed (may ‘block’ these bulks if wide variation is present for certain traits; e.g. height)

- May be able to use machines to select
  - Harvest only tall plants, or save only large seed passed through a sieve

Mass Selection - 2nd Year

- MS really only takes 1 yr because selected seed represents a mixture of only the superior pure lines that existed in the original population

- However, additional rounds of selection and bulking will allow for evaluation under different environments, disease and pest pressures.

- Also, multiple years will allow you to compare performance with established cultivars over years and environments.

Objectives of Mass Selection:

1. To increase the frequency of superior genotypes from a genetically variable population

2. Purify a mixed population with differing phenotypes

3. Develop a new cultivar by improving the average performance of the population

Disadvantages

1. **Selection based on phenotypic performance; not effective with low h^2 traits**

2. **Without progeny testing, heterozygotes can be inadvertently selected**

3. **Population cannot realize maximum potential displayed by the ‘best’ pure line, due to bulking**

4. **Final population is not as uniform as those developed through pure-line selection**

Mass selection vs pure line selection

Line mixture

Mass selection	Pure line selection
Bulk of phenotypically similar plants	Single plant offsprings
	L1 L2 L3……. LN
Cultivar register and marketing	Register and market the best pure lines
Heterogenous cultivars	Homogenous cultivars

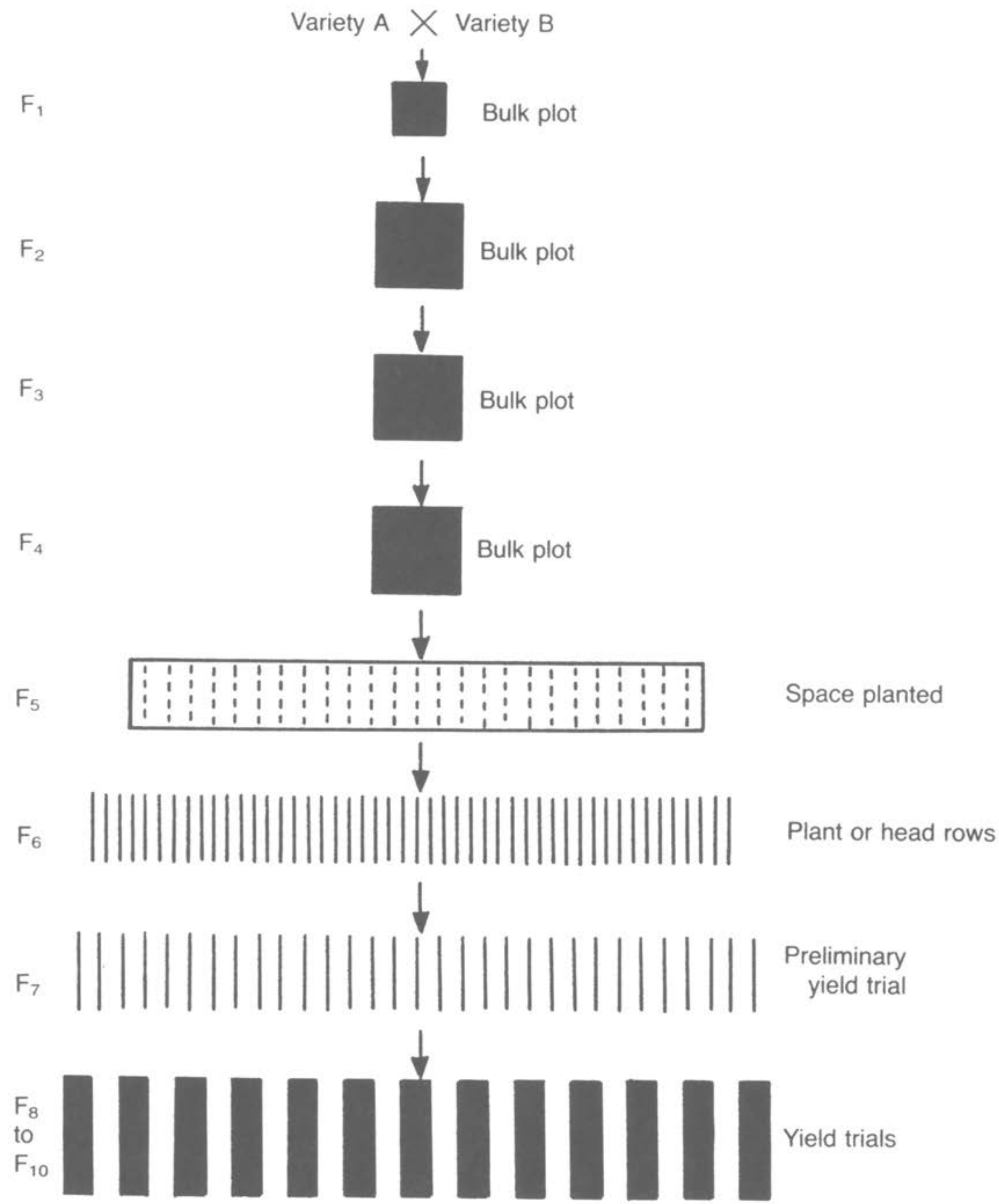
Bulk Method

Bulk

Inbreed in bulk
to have homozygous
lines

Select superior lines
after F6

Crosses with no
high heritability
traits segregating



Points to consider in Bulk Method

1. **Natural selection changes gene freq. via natural survival**
2. **Breeder may assist nature and discard obviously poor types**
3. **Relieves breeder of most record keeping**
4. **Most of us treat bulks with extremely low inputs and low expectations.**

- **The bulk method is a procedure for inbreeding a segregating population until a desired level of homozygosity is reached.**

- **Seed used to grow each selfed generation is a sample of the seed harvested in bulk from the previous generation.**

- **In the bulk method, seeds harvested in the F_1 through F_4 generations are bulked without selection; selection is delayed until advanced generations (F_5-F_8).**

- **By this time, most segregation has stopped.**

Advantages

1. Less record keeping than pedigree
2. Inexpensive
3. Easy to handle more crosses
4. Natural selection is primarily for competitive ability
5. More useful than pedigree method with lower h^2 traits
6. Large numbers of genotypes can be maintained
7. Works well with unadapted germplasm
8. Can be carried on for many years with little effort by the breeder

Disadvantages

1. Environmental changes from season to season so adaptive advantages shift
2. Most grow bulk seed lots in area of adaptation
3. Less efficient than pedigree method on highly heritable traits (because can purge non-selections in early generations)
4. Not useful in selecting plant types at a competitive disadvantage (dwarf types)
5. Final genotypes may be able to withstand environmental stress, but may not be highest yielding
6. If used with a cross pollinated species, inbreeding depression may be a problem

Pedigree Method

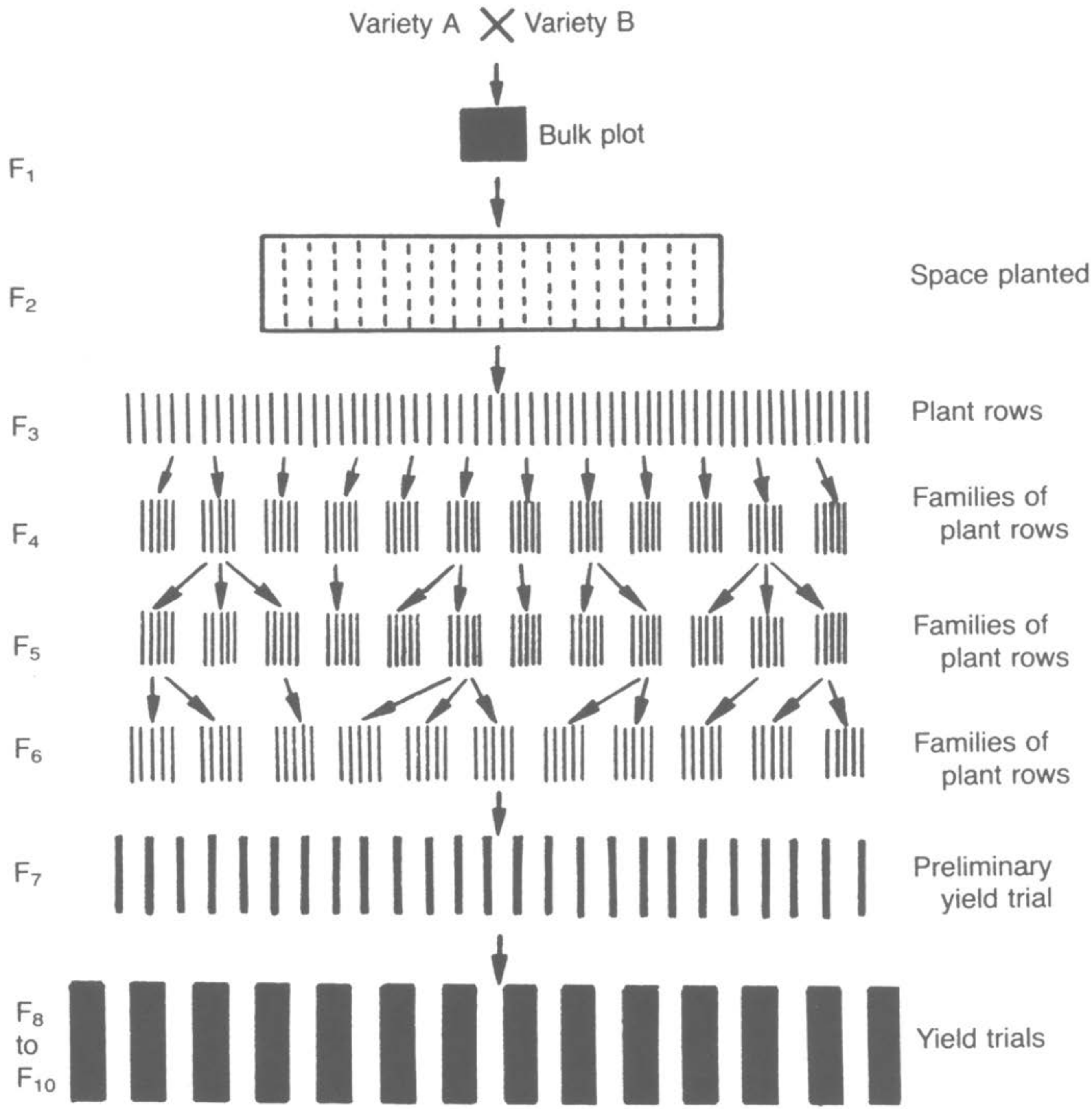
Pedigree Method

- Most popular
- Essentially a plant to row system to develop near pure lines
- Followed by performance testing of resulting strains
- This method and its variants require a lot of record keeping

Pedigree

Selection during inbreeding

Early generations: High heritability traits
Late generations: low heritability traits



Genetic Considerations:

1. Additive genetic variability decreases within lines and increases among lines, assuming no selection

   recall the movement toward homozygosity following the hybridization of unlike and homozygous parents

2. Dominant genetic variability complicates pedigree selection homozygous and heterozygous individuals look alike and therefore you may continually select the heterozygote

THUS, selection can be discontinued with phenotypic uniformity within a line is obtained

Advantages

1. **Eliminates unpromising material at early stages;**

2. **Multi-year records allow good overview of inheritance, and more effective selection through trials in different environments;**

3. **Multiple families (from different F_2 individuals) are maintained yielding different gene combinations with common phenotype**

4. **Allows for comparison to other breeding strategies**

Disadvantages

1. **Most labor, time and resource intensive method; usually compromise between # crosses and population sizes;**

2. **Very dependent on skill of breeder in recognizing promising material;**

3. **Not very effective with low h^2 traits;**

4. **Slow; can usually put through only one generation per year, and the right environmental conditions must be at hand for accurate selection.**

5. **Upper ceiling set by allelic contents of F_2; can not purge selections of undesirable alleles once 'fixed'.**

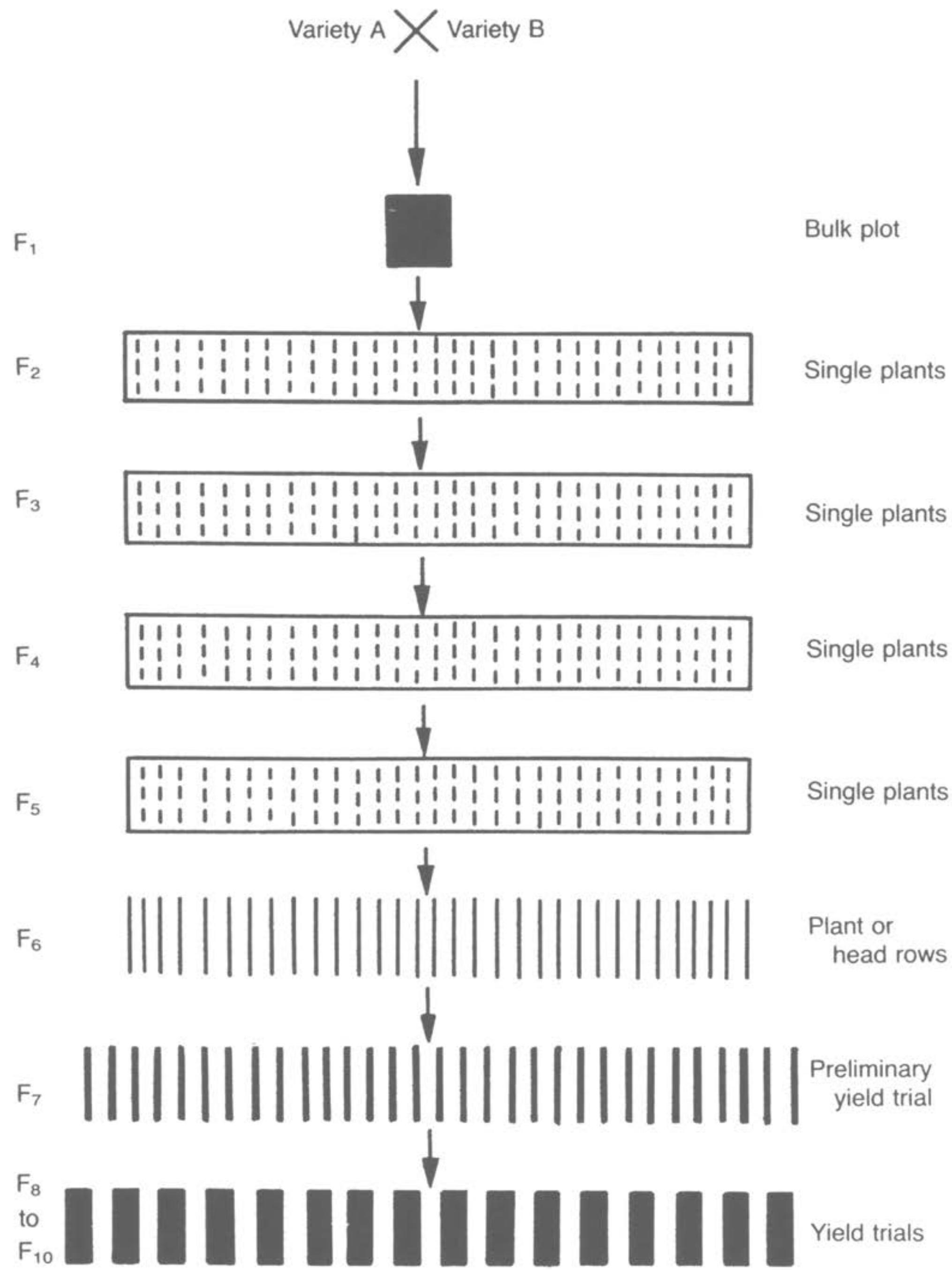
Single Seed Descent

Single Seed Descent

Inbreed with one seed from each plant in each generation

Select superior line after F6

Crosses with no high heritability traits segregating



Advantages

1. Rapid generation advance; 2-4 generations/yr
2. Requires less space,time and resources in early stages, therefore accommodates higher # crosses;
3. Superior to bulk/mass selection if the desired genotype is at a competitive disadvantage; natural selection usually has little impact on population.
4. Delayed selection eliminated confusing effects of heterozygosity; more effective than pedigree breeding when dealing with low h^2 traits;
5. Highly amenable to modifications and can be combined with any method of selection.

Disadvantages

1. May carry inferior material forward

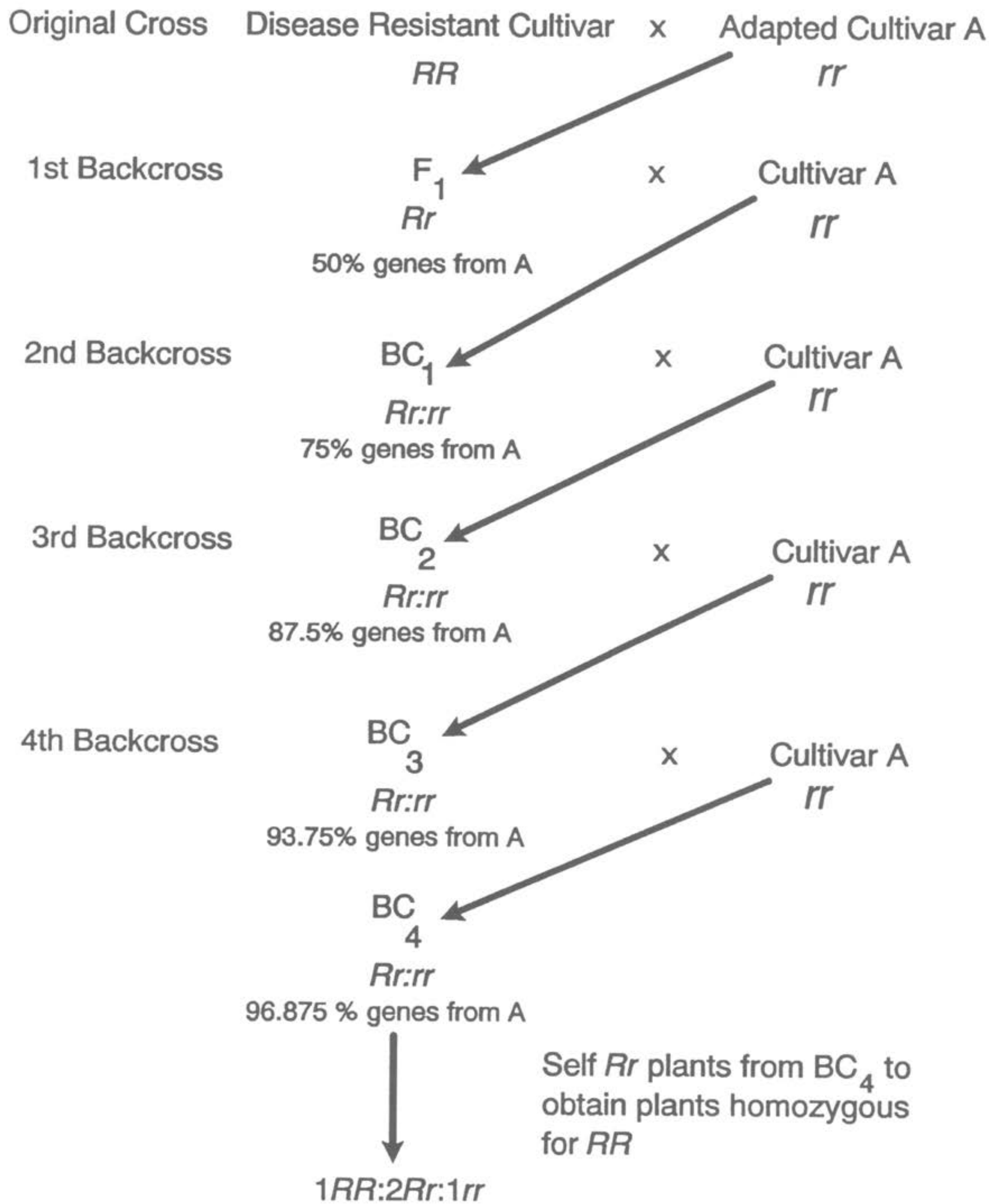
2. Fewer field evaluations, so you lose the advantage of natural selection

3. Need appropriate facilities to allow controlled environment manipulation of plants for rapid seed production cycles (day length, moisture and nutrient control)

Backcross

Backcross

- Same form whether self or cross pollinated species
- Only difference is pollination control
- With backcross we approach homozygosity at the same rate as with selfing
- Goal is to move 1 to a few traits from a donor parent (deficient in other traits) to a recurrent parent (deficient in the trait of interest)


Original Cross
Disease Resistant Cultivar
RR
x
Adapted Cultivar A
rr
1st Backcross
F1
Rr
50% genes from A
x
Cultivar A
rr
2nd Backcross
BC1
Rr:rr
75% genes from A
x
Cultivar A
rr
3rd Backcross
BC2
Rr:rr
87.5% genes from A
x
Cultivar A
rr
4th Backcross
BC3
Rr:rr
93.75% genes from A
x
Cultivar A
rr
BC4
Rr:rr
96.875 % genes from A
Self Rr plants from BC4 to obtain plants homozygous for RR
1RR:2Rr:1rr

Backcross

- Limited use of BC to create a population for selection that fosters wider genetic variance and modest introgression is a separate issue than a repeated BC to derive a new cultivar
- Jensen suggested that a 3-way (a backcross to another recurrent or superior parent following he single cross of a desirable and an undesirable parent) was superior to single cross followed by pedigree or other selection methodology

Backcross

- BC must be used with other, more exploratory procedures; otherwise $G_s=0$
- Must have a suitable recurrent parent
- # of BCs to make? usually 4
- Use several RP plants! WHY?
- To incorporate > 1 trait, use parallel programs and then converge
- Evaluation phase can be less stringent because you should already know the utility of the recurrent parent!

Backcross Breeding

Recovery of the recurrent parent genotype follows this pattern:

	% recurrent	% donor
F_1	50	50
BC_1	75	25
BC_2	87.5	12.5
BC_3	93.7	6.3
BC_4	96.9	3.1
BC_m	$1-(1/2)^{m+1}$	$(1/2)^{m+1}$