Breeding Schemes

- Pure line & multiline
- Out breeding populations & synthetics
- Clones & apomictcs
- Hybrids & synthetics
Breeding Schemes for Pure Line Cultivars

wheat, barley, rice, oat, pea, lentil, rapeseed, chickpea, soybean, millet, flax, tobacco, tomato, etc.
# Homozygosity

<table>
<thead>
<tr>
<th>Parents</th>
<th>AA x aa</th>
<th>Hetero</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>F₁</td>
<td>Aa</td>
<td>100%</td>
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<td></td>
<td>AA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aa</td>
<td>50%</td>
</tr>
<tr>
<td><strong>F₂</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>¼</td>
<td></td>
</tr>
<tr>
<td></td>
<td>½</td>
<td></td>
</tr>
<tr>
<td></td>
<td>¼</td>
<td></td>
</tr>
<tr>
<td><strong>Fₚ</strong></td>
<td></td>
<td></td>
</tr>
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<tbody>
<tr>
<td><strong>F&lt;sub&gt;1&lt;/sub&gt;</strong></td>
<td>Aa</td>
<td>100%</td>
</tr>
<tr>
<td><strong>F&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td>AA 1/4, Aa 1/2, aa 1/4</td>
<td>50%</td>
</tr>
<tr>
<td><strong>F&lt;sub&gt;3&lt;/sub&gt;</strong></td>
<td>AA 1/4, aa 1/4</td>
<td>25%</td>
</tr>
</tbody>
</table>
## Homozygosity

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<td>100%</td>
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<td>AA</td>
<td>50%</td>
</tr>
<tr>
<td>F&lt;sub&gt;3&lt;/sub&gt;</td>
<td>AA</td>
<td>25%</td>
</tr>
</tbody>
</table>

### F<sub>2</sub> Frequencies

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>1/4</td>
</tr>
<tr>
<td>Aa</td>
<td>1/2</td>
</tr>
<tr>
<td>aa</td>
<td>1/4</td>
</tr>
</tbody>
</table>

### F<sub>3</sub> Frequencies

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>1/4</td>
</tr>
<tr>
<td>AA</td>
<td>1/8</td>
</tr>
<tr>
<td>Aa</td>
<td>1/4</td>
</tr>
<tr>
<td>aa</td>
<td>1/8</td>
</tr>
<tr>
<td>aa</td>
<td>1/4</td>
</tr>
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</table>
## Homozygosity

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</tr>
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<tbody>
<tr>
<td><strong>F1</strong></td>
<td></td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td><strong>F2</strong></td>
<td>AA</td>
<td>Aa</td>
</tr>
<tr>
<td><strong>F3</strong></td>
<td>AA</td>
<td>Aa</td>
</tr>
<tr>
<td><strong>Frequencies</strong></td>
<td>$\frac{1}{4}$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>$\frac{3}{8}$</td>
<td>$\frac{1}{4}$</td>
<td>$\frac{3}{8}$</td>
</tr>
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</table>
Consider an F₁ that is heterozygous at \( n \) loci; heterozygosity \( (h) \) after \( g \) generations \( (g = 0 \) at F₁) of selfing will be:

\[
h = (1/2)^g
\]

The probability of homozygosity at \( n \) loci will be:

\[
p = (1-h)^n
\]

Hence after \( g \) generations:

\[
p = [1-(1/2)^g]^n
\]

or

\[
p = [(2^g-1)/2^g]^n
\]
Consider an F₁ that is heterozygous at 6 loci; heterozygosity \( h \) after 3 generations \( (g = 3 \text{ is } F_4) \) of selfing will be:

\[
h = (1/2)^3 = 1/16
\]

The probability of homozygosity at 6 loci will be:

\[
p = (1-h)^6 = (15/16)^6 = 67.9\%
\]
Accelerating Homozygosity

- Single Seed Descent (SSD)
- Off-season sites
- Double haploids
Bulk Breeding Scheme
Crossing

$F_1$

$F_5$

$\rightarrow$

Bulk Population (mass selection)
Crossing

\[ \begin{align*}
F_1 \\
\downarrow \\
F_5 \\
\downarrow \\
F_6
\end{align*} \]

\{ Bulk Population (mass selection) \}

\[ \begin{align*}
\text{Single plants}
\end{align*} \]

Bulk Population

Single plants
Crossing

\[ F_1 \]

\[ F_5 \]

\{ Bulk Population (mass selection) \}

\[ F_6 \]

Single plants

\[ F_7 \]

Head rows
Crossing

\[ \begin{align*}
\text{F}_1 & \\
\downarrow & \\
\text{F}_5 & \\
\end{align*} \]

\{ Bulk Population (mass selection) \}

\[ \begin{align*}
\text{F}_6 & \\
\downarrow & \\
\text{F}_7 & \\
\downarrow & \\
\text{F}_{8-9} & \\
\end{align*} \]

Single plants

Head rows

Early yield trials
Crossing

F₁

F₅

Bulk Population (mass selection)

F₆

F₇

F₈-9

F₉-10

Single plants

Head rows

Early yield trials

Advanced yield trials

Cultivar
Bulk Breeding Scheme Disadvantages

- Time between initial cross and first yield trials.
- Natural selection during the bulked towards homozysosity stage is not always advantageous.
Conscious selection is not attempted until near-homozygosity. Avoids difficulty of selecting amongst segregating lines where dominance effects can be large. Least inexpensive. Revised interest with use of doubled haploids and SSD.
Pedigree Breeding Scheme
Crossing

F_1
Crossing

F₁

F₂

Single plants
Crossing

F₁

F₂

F₃

Single plants

Head rows
Crossing

F₁

F₂

F₃

F₄

Single plants

Head rows

Head rows
Crossing

F_1

F_2

F_3

F_4

F_5

F_6-7

Single plants

Head rows

Head rows

Head rows

Early yield trials
Crossing

F_1

F_2

F_3

F_4

F_5

F_6-7

F_8-9

Single plants

Head rows

Head rows

Head rows

Early yield trials

Advanced yield trials

Cultivar
Pedigree Breeding Scheme Disadvantages

- Laborious with considerable record keeping.
- Expensive, requires more land.
- Experiences staff needed with “good eye”.
- Selection inefficient on single plants.
- No actual earley generation yield testing.
Pedigree Breeding Scheme
Advantages

- If single plant selection is efficient, inferior genotypes are discarded without expensive yield testing.
Pedigree/Bulk Breeding Scheme
Crossing

\[ F_1 \]

\[ F_2 \quad \vdots \quad F_3 \]

Single Plants

Head row 1
Crossing

$F_1$

$F_2$

$F_3$

$F_4$

$F_5$

$F_6$

Single Plants

Head row 1

Bulk yield 1

Bulk yield 2

Head row 2
Crossing

F_1

F_2

F_3

F_4

F_5

F_6

F_7

F_8

F_9-10

Single Plants

Head row 1

Bulk yield 1

Bulk yield 2

Head row 2

Bulk yield 3

Early yield trials

Advanced yield trials

Cultivar
Pedigree/Bulk Breeding Scheme Disadvantages

- Early generation testing can limit testing of more advanced inbred lines.
- Lengthy time between crossing and final release.
Pedigree/Bulk Breeding Scheme Advantages

- Combines best features of pedigree and bulk schemes.
- Inferior lines discarded early in the scheme.
- More than a single cultivars may derive from a population or heterogenous line.
Modified Pedigree/Bulk Scheme
Crossing

$F_1$

$F_2$

$F_3$

Single Plants

Head rows
Crossing

\[ F_1 \]

\[ F_2 \rightarrow \text{Single Plants} \]

\[ F_3 \rightarrow \text{Head rows} \]

\[ F_4 \rightarrow \text{Head rows \& Yield 1} \]
Crossing

F₁

F₂

F₃

F₄

F₅

Single Plants

Head rows

Head rows & Yield 1

Head rows & Yield 2
Crossing

\[ F_1 \]

\[ F_2 \]

\[ F_3 \]

\[ F_4 \]

\[ F_5 \]

\[ F_7 \]

Single Plants

Head rows

Head rows & Yield 1

Head rows & Yield 2

Early yield trials
Crossing

F₁

F₂

F₃

F₄

F₅

F₇

F₈₉

Single Plants

Head rows

Head rows & Yield 1

Head rows & Yield 2

Early yield trials

Advanced yield trials

Cultivar

F₈₉

F₁

Cultivar
Modified Pedigree/Bulk Scheme Disadvantages

- Very intensive.
- High level of cross reference and record keeping.
- If not applied correctly, can combine the worst aspects of the pedigree and bulk schemes.
Pedigree/Bulk Breeding Scheme Advantages

- Combines best features of pedigree and bulk schemes.
- Allows quantitative selection in the early generations.
- Very quick from cross to cultivar.
Seed increases and Cultivar release

- Seed classes: Breeders’ seed; Foundation seed; Certified seed; Registered seed.
- Mass selection.
- Progeny Testing.
Multilines
Isogenic lines
Backcrossing
$1 - (1/2)^{g-1}$
Backcrossing

Wild x Adapted

F₁ x Adapted

BC₁F₁ x Adapted

BC₂F₁ x Adapted

BC₃F₁ x Adapted

Select for resistance

Select for resistance

Select for resistance

Select for resistance

Select Homozygous resistant

Self

F₁

BC₁F₁

BC₂F₁

BC₃F₁

BC₄F₁

50.0%

75.0%

87.5%

94.8%

96.9%
Breeding Schemes for open pollinated cultivars and synthetics (next)