UNIVERSIDADE DE SÃO PAULO
ESCOLA SUPERIOR DE AGRICULTURA
"LUIZ DE QUEIROZ"
DEPARTAMENTO DE GENÉTICA
LGN5825 Genética e Melhoramento de Espécies Alógamas

Hybrids between lines

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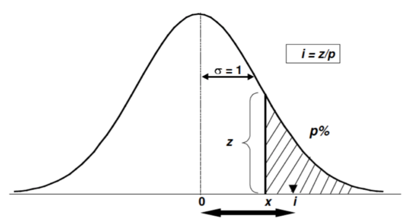
Hybrids

- Cross between two divergent but complementary lines

- Normally, they belong to different heterotic groups

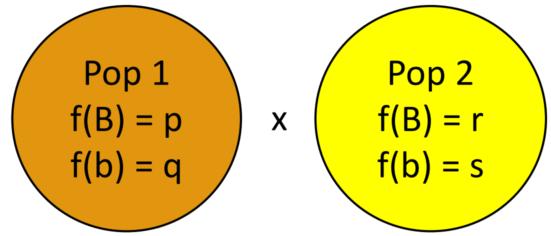
- Why hybrids?
- *Combine traits that are in different parents*
- *Take advantage of heterosis*
- *Uniformity*
- *Just the best genotype (single-cross)*
- *Market seed control*


***dent* – tuxpeño** ***flint* – cateto**



Types of Hybrids

- SC- Single-cross – A x B
- TWC - Three-way cross - (A x A') x B
- DC - Double-Cross - (A x A') x (B x B')
- Predictions by Jenkins



$$TWC_{(12)3} = \frac{(SC_{13} + SC_{23})}{2} \qquad DC_{(12)(34)} = \frac{(SC_{13} + SC_{23} + SC_{14} + SC_{24})}{4}$$

- Heterozygous, "homogeneous", and high technology
- Number of hybrids (based on the groups)
- $N_{SC} = NL_1\ NL_1 - 1 \text{ x } NL_2$
- $N_{SC} = NL_1(NL_1 - 1)/2 \text{ x } NL_2$
- $N_{SC} = NL_1(NL_1 - 1)/2 \text{ x } NL_2(NL_2 - 1)/2$

Predicting hybrids

- TC - Three-way cross - (A x A') x B

Parents	Gametes	Possible TWC	GV
SC_{12} AaBb (AABB x aabb)	AB Ab aB ab	AABb	$u + \boldsymbol{\alpha}_A + d_{Bb}$
		AAbb	$u + \boldsymbol{\alpha}_A - \boldsymbol{\alpha}_b$
L3 AAbb	Ab	AaBb	$u + d_{Aa} + d_{Bb}$
		Aabb	$u + d_{Aa} - \boldsymbol{\alpha}_b$
Mean		$u + ½ (\boldsymbol{\alpha}_A - \boldsymbol{\alpha}_b + d_{Aa} + d_{Bb})$	

SC non-parents	Genotype	GV
SC_{13}	AABb	$u + \boldsymbol{\alpha}_A + d_{Bb}$
SC_{23}	Aabb	$u + d_{Aa} - \boldsymbol{\alpha}_b$
Mean		$u + ½ (\boldsymbol{\alpha}_A - \boldsymbol{\alpha}_b + d_{Aa} + d_{Bb})$

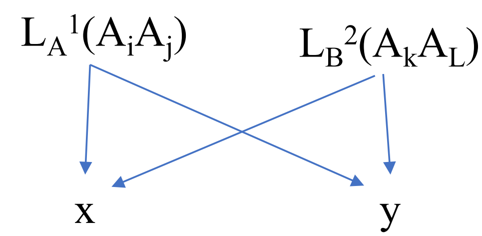
Covariance and response to selection in hybrids

- $COV_g(X_{ij(12)}, y_{ij(12)}) = f_{xy1}Va_{12} + f_{xy2}Va_{21} + u_{xy12}Vd_{12}$
- $f_{xy1} = ½\ [P(x_i^1 \equiv y_i^1)]$
- $f_{xy2} = ½\ [P(x_j^2 \equiv y_j^2)]$
- $u_{xy12} = P(x_i^1 \equiv y_i^1) = P(x_j^2 \equiv y_j^2) = P(x_i^1 \equiv y_i^1; x_j^2 \equiv y_j^2)$
- As they different populations, the latter can be reduced to
- $u_{xy12} = 2f_{xy1}Va_{12} + 2f_{xy2}Va_{21}$

$$RS = \frac{i}{\sigma_P} COV_G(x,y)$$

$$RS = \frac{i}{\sigma_P}\sigma_H^2$$

- Single-cross
- $f_{xy1} = ½\ [P(x \equiv y \equiv A_i) + P(x \equiv y \equiv A_j) + 2.P(x \equiv y \equiv A_j \equiv A_j)]$
- ½ ½ ½ ½ ½ ½ F
- $f_{xy1} = ½\ [¼ + ¼ + 2.¼.F] = ¼(1+F)$
- $f_{xy2} = ½\ [P(x \equiv y \equiv A_k) + P(x \equiv y \equiv A_L) + 2.P(x \equiv y \equiv A_K \equiv A_L)] = ¼(1+F)$
- $u_{xy12} = 2f_{xy1}Va_{12} + 2f_{xy2}Va_{21} = 2.¼(1+F) + 2.¼(1+F) = ¼(1+F)^2$
- $COV_{gSC12} = ¼(1+F)[Va_{12} + Va_{21}] + ¼(1+F)^2 Vd_{12}$



Covariance and response to selection in hybrids

- $COV_{gSC12} = ¼(1+F)[Va_{12} + Va_{21}] + ¼(1+F)^2Vd_{12}$

- Thus, for SC between S_1 lines (F = 0 = parents F)
- $COV_{gSC12} = ¼(1+0)[Va_{12} + Va_{21}] + ¼(1+0)^2Vd_{12}$
- $COV_{gSC12} = ¼[Va_{12} + Va_{21}] + ¼Vd_{12}$

- and for SC between inbred lines (F=1)
- $COV_{gSC12} = ¼(1+1)[Va_{12} + Va_{21}] + ¼(1+1)^2Vd_{12}$
- $COV_{gSC12} = ½[Va_{12} + Va_{21}] + Vd_{12}$

- The latter takes advantage of all the dominance and additive genetic variability
- Therefore, there is no VG within hybrids, just among them

Covariance and response to selection in hybrids

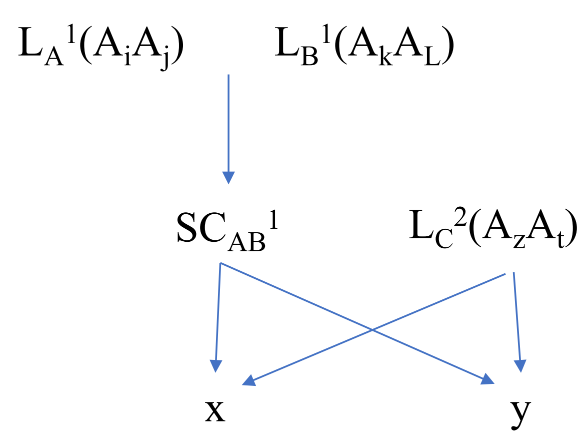
- Three-way cross
- $f_{xy1} = ½ [P(x \equiv y \equiv A_i) + P(x \equiv y \equiv A_j) + 2.P(x \equiv y \equiv A_j \equiv A_j) +$
- ¼ ¼ ¼ ¼ ¼ ¼ F
- $+ P(x \equiv y \equiv A_k) + P(x \equiv y \equiv A_L) + 2.P(x \equiv y \equiv A_K \equiv A_L)]$
- $f_{xy1} = ½ [1/16 + 1/16 + 2. 1/16.F + 1/16 + 1/16 + 2. 1/16.F] = 1/8(1+F)$

- $f_{xy2} = ½ [P(x \equiv y \equiv A_z) + P(x \equiv y \equiv A_t) + 2.P(x \equiv y \equiv A_z \equiv A_t)]$
- $f_{xy2} = ½ [¼ + ¼ + 2.¼.F] = ¼(1+F)$

- $u_{xy12} = 2f_{xy1}Va_{12} + 2f_{xy2}Va_{21} = 2. 1/8(1+F) +2. ¼(1+F) = 1/8(1+F)^2$

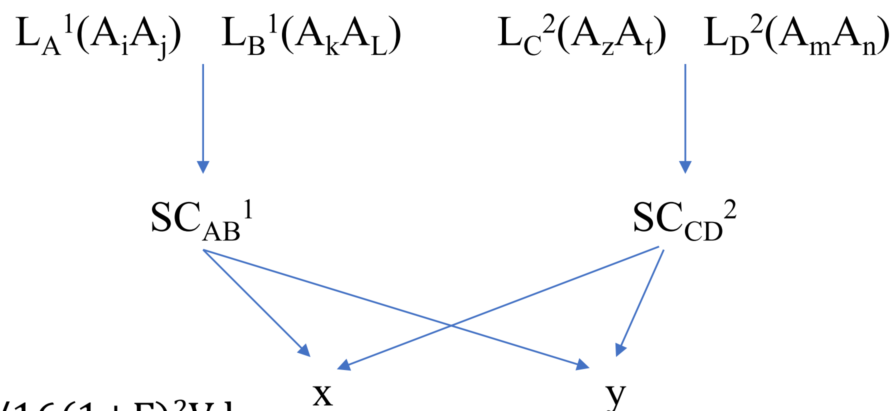
- $COV_{gTWC(12)3} = 1/8(1+F)Va_{12} + 1/4(1+F)Va_{21} + 1/8(1+F)^2Vd_{12}$

- TWC between S_1 lines (F = 0 = parents F)
- $COV_{gTWC(12)3} = 1/8Va_{12} + 1/4Va_{21} + 1/8Vd_{12}$
- TWC between inbred lines (F=1)
- $COV_{gTWC(12)3} = 1/4Va_{12} + 1/2Va_{21} + 1/2 Vd_{12}$



Covariance and response to selection in hybrids

- Double-cross
- $f_{xy1} = 1/8(1+F)$
- $f_{xy2} = 1/8(1+F)$
- $u_{xy12} = 1/16(1+F)^2$
- $COV_{gDC(12)(34)} = 1/8(1+F)Va_{12} + 1/8(1+F)Va_{21} + 1/16(1+F)^2Vd_{12}$



- DC between S_1 lines (F = 0 = parents F)
- $COV_{gDC(12)(34)} = 1/8Va_{12} + 1/8Va_{21} + 1/16Vd_{12}$

- DC between inbred lines (F=1)
- $COV_{gDC(12)(34)} = 1/4Va_{12} + 1/4Va_{21} + 1/4\,Vd_{12}$

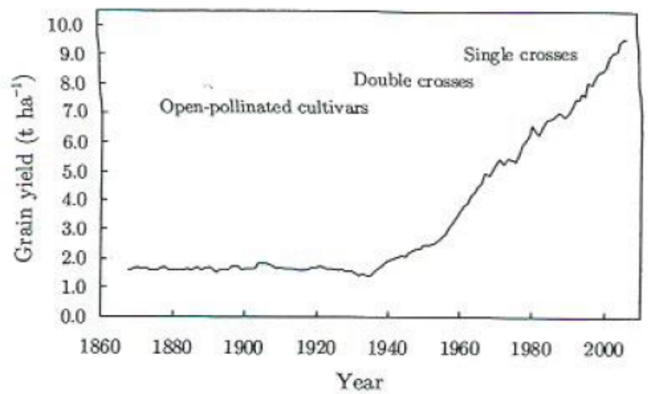
Comparison among cultivars

Hybrid	Vg (among)			Vg (within)		
	Va_{12}	Va_{21}	Vd_{12}	Va_{12}	Va_{21}	Vd_{12}
SC	1/2	1/2	1	0	0	0
TWC	1/4	1/2	1/2	1/4	0	1/2
DC	1/4	1/4	1/4	1/4	1/4	3/4

Cost, yield, heterosis, homogeneity, and technology →

Varieties DC TWC SC

← Variability and yield stability



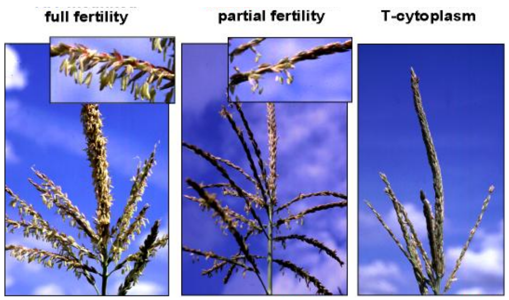
Obtaining hybrids

- SC – ratio **male:female** 1:2 to 1:3 (3 field of crosses)
- TWC - 1:2 to 1:3 (5 fields)
- DC - 1:6 (7 fields)

- Seed cost x Yield
- *Female parent*

- How can we avoid contaminations?
- Coincidence of flowering dates
- Remove the tassels
- Distance of 300m between fields
- Time interval between fields - 20 to 30 days

Male-sterility



Double-Cross

♀ L1 x **♂ L2**

Cit. sterile
Nucleus *rfrf*
100% sterile

Cit. normal
Nucleus *rfrf*
100% fertile

♀ L3 x **♂ L4**

Cit. sterile
Nucleus *rfrf*
100% sterile

Cit. normal
Nucleus *RfRf*
100% fertile

♀ SC 12
Cit. sterile
Nucleus *rfrf*
100% sterile

x

♀ SC 34
Cit. sterile
Nucleus *Rfrf*
100% fertile

DC (12)(34)
Cit. sterile
½ fertile ½ sterile

Single-cross