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“LUIZ DE QUEIROZ”
DEPARTAMENTO DE GENÉTICA
LGN5825 Genética e Melhoramento de Espécies Alógamas



Hybrids between lines

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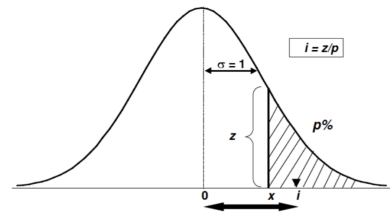
Hybrids

- 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*



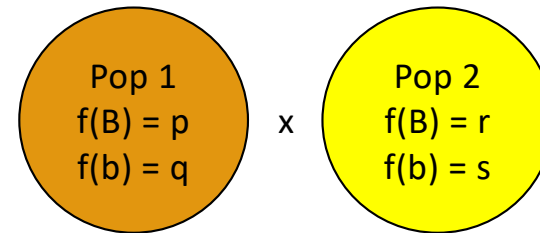
dent – tuxpeño

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



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

- Heterozygous, “homogeneous”, and high-technology
- Number of hybrids (based on the groups)
- $N_{SC} = NL_1 \times NL_2$
- $N_{TWC} = NL_1(NL_1-1)/2 \times NL_2 + NL_2(NL_2-1)/2 \times NL_1$
- $N_{DC} = NL_1(NL_1-1)/2 \times NL_2(NL_2-1)/2$

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 + α _A + d _{Bb}
		AAbb	u + α _A - α _b
L3 AAbb	Ab	AaBb	u + d _{Aa} + d _{Bb}
		Aabb	u + d _{Aa} - α _b
Mean		u + ½ (α _A - α _b + d _{Aa} + d _{Bb})	

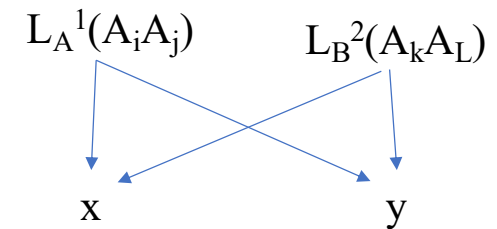
SC non-parents	Genotype	GV
SC ₁₃	AABb	$u + \alpha_A + d_{Bb}$
SC ₂₃	Aabb	$u + d_{Aa} - \alpha_b$
Mean		$u + \frac{1}{2} (\alpha_A - \alpha_b + d_{Aa} + d_{Bb})$

Covariance and response to selection in hybrids

- $COV_g(X_{ij(12)}, y_{ij(12)}) = f_{xy1}Va_{12} + f_{xy2}Va_{21} + u_{xy12}Vd_{12}$
- $f_{xy1} = \frac{1}{2} [P(x_i^1 \equiv y_i^1)]$
- $f_{xy2} = \frac{1}{2} [P(x_j^2 \equiv y_j^2)]$
- $u_{xy12} = P(x_i^1 \equiv y_i^1) = P(x_j^2 \equiv y_j^2) = P(x_i^1 \equiv y_i^1; x_j^2 \equiv y_j^2)$
- **As they different populations, the latter can be reduced to**
- $u_{xy12} = 2f_{xy1}Va_{12} \cdot 2f_{xy2}Va_{21}$
- **The covariance within is equal to variance between**
- **Single-cross**
- $f_{xy1} = \frac{1}{2} [P(x \equiv y \equiv A_i) + P(x \equiv y \equiv A_j) + 2.P(x \equiv y \equiv A_j \equiv A_i)]$
- $\frac{1}{2} \quad \frac{1}{2} \quad \frac{1}{2} \quad \frac{1}{2} \quad \frac{1}{2} \quad \frac{1}{2} \quad F$
- $f_{xy1} = \frac{1}{2} [\frac{1}{4} + \frac{1}{4} + 2 \cdot \frac{1}{4} \cdot F] = \frac{1}{4}(1+F)$
- $f_{xy2} = \frac{1}{2} [P(x \equiv y \equiv A_k) + P(x \equiv y \equiv A_L) + 2.P(x \equiv y \equiv A_k \equiv A_L)] = \frac{1}{4}(1+F)$
- $u_{xy12} = 2f_{xy1}Va_{12} \cdot 2f_{xy2}Va_{21} = 2 \cdot \frac{1}{4}(1+F) \cdot 2 \cdot \frac{1}{4}(1+F) = \frac{1}{4}(1+F)^2$
- $COV_{gSC12} = \frac{1}{4}(1+F)[Va_{12} + Va_{21}] + \frac{1}{4}(1+F)^2Vd_{12}$

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

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



Covariance and response to selection in hybrids

- $COV_{gSC12} = \frac{1}{4}(1+F)[Va_{12} + Va_{21}] + \frac{1}{4}(1+F)^2Vd_{12}$
- Thus, for SC between S_1 lines ($F = 0 = \text{parents } F$)
- $COV_{gSC12} = \frac{1}{4}(1+0)[Va_{12} + Va_{21}] + \frac{1}{4}(1+0)^2Vd_{12}$
- $COV_{gSC12} = \frac{1}{4}[Va_{12} + Va_{21}] + \frac{1}{4}Vd_{12}$
- and for SC between inbred lines ($F=1$)
- $COV_{gSC12} = \frac{1}{4}(1+1)[Va_{12} + Va_{21}] + \frac{1}{4}(1+1)^2Vd_{12}$
- $COV_{gSC12} = \frac{1}{2}[Va_{12} + Va_{21}] + Vd_{12}$
- The latter takes advantage of all the dominance and additive genetic variability
- Therefore, there is no VG within hybrids, just among them
- The covariance within is equal to variance between

Covariance and response to selection in hybrids

- **Three-way cross**

- $f_{xy1} = \frac{1}{2} [P(x \equiv y \equiv A_i) + P(x \equiv y \equiv A_j) + 2.P(x \equiv y \equiv A_i \equiv A_j) +$

- $\quad \quad \quad \frac{1}{4} \quad \frac{1}{4} \quad \quad \quad \frac{1}{4} \quad \frac{1}{4} \quad \quad \quad \frac{1}{4} \quad \frac{1}{4} \quad \quad \quad F$
- $\quad \quad \quad + P(x \equiv y \equiv A_k) + P(x \equiv y \equiv A_L) + 2.P(x \equiv y \equiv A_k \equiv A_L)]$

- $f_{xy1} = \frac{1}{2} [1/16 + 1/16 + 2.1/16.F + 1/16 + 1/16 + 2.1/16.F] = \frac{1}{8}(1+F)$

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

- $f_{xy2} = \frac{1}{2} [\frac{1}{4} + \frac{1}{4} + 2.\frac{1}{4}.F] = \frac{1}{4}(1+F)$

- $u_{xy12} = 2f_{xy1}Va_{12} . 2f_{xy2}Va_{21} = 2.1/8.(1+F) . 2.\frac{1}{4}(1+F) = \frac{1}{8}(1+F)^2$

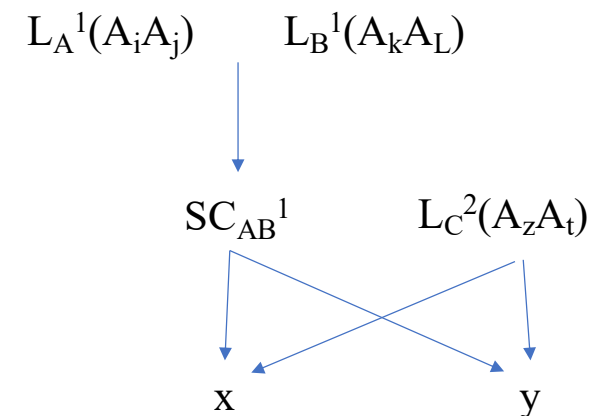
- $COV_{gTWC(12)3} = 1/8(1+F)Va_{12} + 1/4(1+F)Va_{21} + 1/8(1+F)^2Vd_{12}$

- TWC between S_1 lines ($F = 0 = \text{parents } F$)

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

- 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

- $f_{xy1} = 1/8(1+F)$

- $f_{xy2} = 1/8(1+F)$

- $u_{xy12} = 1/16(1+F)^2$

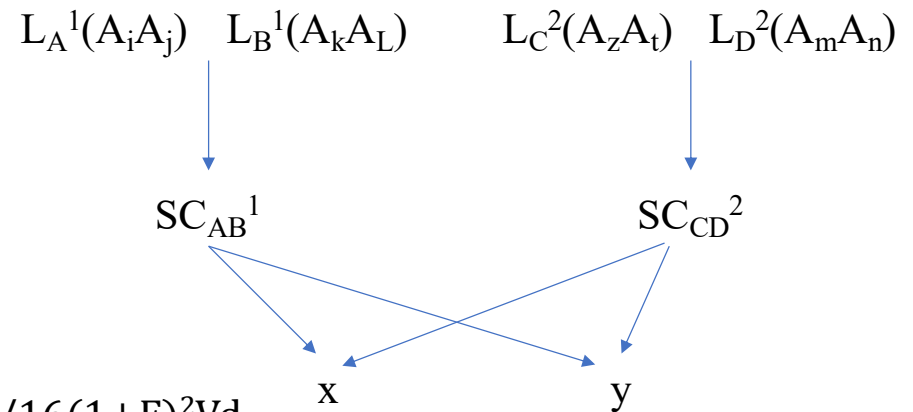
- $COV_{gDC(12)(34)} = 1/8(1+F)Va_{12} + 1/8(1+F)Va_{21} + 1/16(1+F)^2Vd_{12}$

- DC between S_1 lines ($F = 0 = \text{parents } F$)

- $COV_{gDC(12)(34)} = 1/8Va_{12} + 1/8Va_{21} + 1/16Vd_{12}$

- DC between inbred lines ($F=1$)

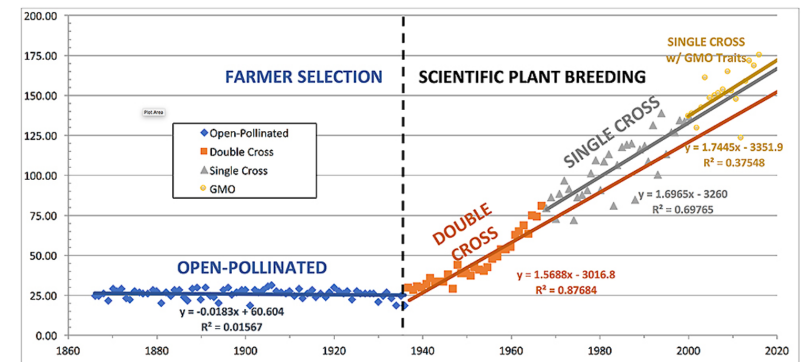
- $COV_{gDC(12)(34)} = 1/4Va_{12} + 1/4Va_{21} + 1/4Vd_{12}$



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



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

