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DEPARTAMENTO DE GENÉTICA  
LGN5825 Genética e Melhoramento de Espécies Alógamas



# Base populations and breeding schemes

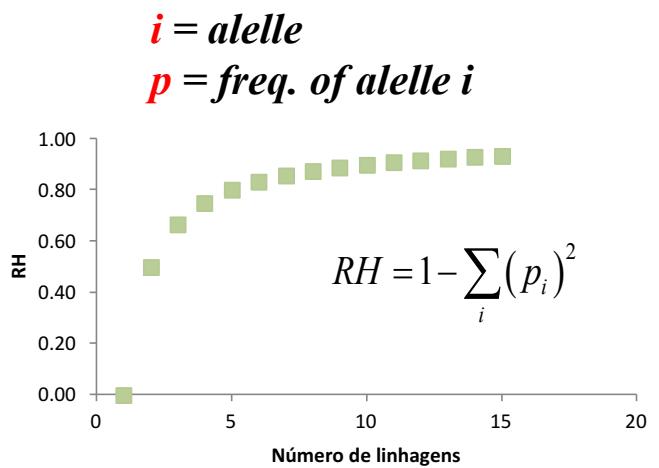
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# Building a base population

- Combine high mean and large variability
- Open mating among parents
- Closed system – *since the begin, all the alleles are in the base population*
- HWE - binomial and multinomial distributions (**% heterozygosity**)
- **How many parents?**
- Variability vs. Mean vs. Heterozygosity
- Number of cycles vs. Ne
- What is the maximum of RS?     $RS = 2.Ne.i.r_{aP}.\sigma_a$
- Choosing parents:
  - *Breeding program objectives*
  - *Heterotic Groups (SCA and GCA)*



# Which is the best base population?

- Combine mean and variability (divergence)
- $L_1 = AABBCC$
- $L_2 = aabbCC$
- $L_1 = u + \alpha_a + \alpha_b + \alpha_c$
- $L_2 = u - \alpha_a - \alpha_b + \alpha_c$
- $X_{P(12)} = u + \alpha_c$
- $L_1 = AABBCC$
- $L_2 = AAbbCC$
- $L_3 = aaBBCC$
- $L_4 = aabbCC$
- $L_1 = u + \alpha_a + \alpha_b + \alpha_c$
- $L_2 = u + \alpha_a - \alpha_b + \alpha_c$
- $L_3 = u - \alpha_a + \alpha_b + \alpha_c$
- $L_4 = u - \alpha_a - \alpha_b + \alpha_c$
- $X_{P(1234)} = u + \alpha_c$
- Which are the best populations to obtain lines?
- $X_S = u + (p - q)a + 2pqd - 2pqdF$
- $X_{S0} = u + (p - q)a + 2pqd$
- $X_{S1} = u + (p - q)a + pqd$
- The best can be estimated by  $= 2.X_{S1} - X_{S0}$
- $2u + 2(p - q)a + 2pqd - (u + (p - q)a + 2pqd)$
- $u + (p - q)a$  (estimated value for  $F = 1$ )

# Why after so many cycles there is Va?

- Two-locus model =  $A_iA_j / B_kB_l$
- $G_{ijkl} = (\alpha_i + \alpha_j + S_{ij}) + (\alpha_k + \alpha_l + S_{kl}) + I_{ijkl}$
- $G_{ijkl} = u + A_{ij} + B_{kl} + I_{ijkl}$
- The epistatic effect is
- $I_{ijkl} = G_{ijkl} - (u + A_{ij} + B_{kl})$
- 1 or 2 dominant allele = 13
- Otherwise = 1
- $p = q = 0.5$
- Population mean
- $u = p^2p^2G_{1111} + p^22pqG_{1112} + \dots + q^2q^2G_{2222}$
- $= \frac{1}{4} \cdot \frac{1}{4} \cdot 13 + \frac{1}{4} \cdot \frac{1}{2} \cdot 13 + \dots + \frac{1}{4} \cdot \frac{1}{4} \cdot 1 = 12\frac{1}{4}$
- $A_iA_j$  and  $B_kB_l$  effects
- $G_{22..} = p^213 + 2pq13 + q^21 = 10$
- $A_{22} = G_{ij..} - u = 10 - 12\frac{1}{4} = -9/4$
- $I_{ijkl}$  effect
- $I_{1111} = G_{1111} - (u + A_{11} + B_{11})$   
 $= 13 - (12 + \frac{1}{4}) - \frac{3}{4} - \frac{3}{4} = -\frac{3}{4}$

	$B_1B_1$	$B_1B_2$	$B_2B_2$	$G_{ij..}$	$A_{ij..}$	
$A_1A_1$	$G_{1111} = 13$	$G_{1112} = 13$	$G_{1122} = 13$	$G_{11..} = 13$	$A_{11} = \frac{3}{4}$	
	$u+A_{11}+B_{11} = 13\frac{3}{4}$	$u+A_{11}+B_{12} = 13\frac{3}{4}$	$u+A_{11}+B_{22} = 10\frac{3}{4}$			
	$I_{1111} = -\frac{3}{4}$	$I_{1112} = -\frac{3}{4}$	$I_{1122} = 9/4$			
$A_1A_2$	$G_{1211} = 13$	$G_{1212} = 13$	$G_{1222} = 13$	$G_{12..} = 13$	$A_{12} = \frac{3}{4}$	
	$u+A_{12}+B_{11} = 13\frac{3}{4}$	$u+A_{12}+B_{12} = 13\frac{3}{4}$	$u+A_{12}+B_{22} = 10\frac{3}{4}$			
	$I_{1211} = -\frac{3}{4}$	$I_{1212} = -\frac{3}{4}$	$I_{1222} = 9/4$			
$A_2A_2$	$G_{2211} = 13$	$G_{2212} = 13$	$G_{2222} = 1$	$G_{22..} = 10$	$A_{22} = -9/4$	
	$u+A_{22}+B_{11} = 10\frac{3}{4}$	$u+A_{22}+B_{21} = 10\frac{3}{4}$	$u+A_{22}+B_{22} = 7\frac{3}{4}$			
	$I_{2211} = 9/4$	$I_{2212} = 9/4$	$I_{2222} = -27/4$			
$G_{..kl}$	$G_{..11} = 13$	$G_{..12} = 13$	$G_{..22} = 10$	$u = 12\frac{1}{4}$		
$B_{kl}$	$B_{11} = \frac{3}{4}$	$B_{12} = \frac{3}{4}$	$B_{22} = -9/4$			

# Why after so many cycles there is Va?

- Considering  $AA = Aa = 13$  and  $aa = 10$
- $a = d = 3/2$
- $Va = 2pq[a + (p - q)d]^2$
- $= 2 \frac{1}{2} \frac{1}{2} [3/2 + (\frac{1}{2} - \frac{1}{2})3/2)$
- $= 9/8 = 1.12$
- $Vd = (2pqd)^2$
- $= (2 \frac{1}{2} \frac{1}{2} 3/2)^2$
- $= 9/16 = 0.56$
- The same values are found for B. Thus,
- $Va = VaA + VaB = 2.25$
- $Vd = VdA = VdB = 1.12$
- $Vg = \frac{1}{4} \frac{1}{4} (13 - (12 + 1/4))^2 + \dots + \frac{1}{4} \frac{1}{4} (1 - 12 \frac{1}{4})^2$
- $= 135/16 = 8.44$
- $Vi = Vg - Va - Vd = 81/16 = 5.06$
- $Va = 13.33 \%$
- $Vd = 6.66 \%$
- $Vi = 80.01\%$

	B <sub>1</sub> B <sub>1</sub>	B <sub>1</sub> B <sub>2</sub>	B <sub>2</sub> B <sub>2</sub>	G <sub>ij..</sub>	A <sub>ij..</sub>
A <sub>1</sub> A <sub>1</sub>	G <sub>1111</sub> = 13	G <sub>1112</sub> = 13	G <sub>1122</sub> = 13	G <sub>11..</sub> = 13	A <sub>11</sub> = $\frac{3}{4}$
	u+A <sub>11</sub> +B <sub>11</sub> = $13\frac{3}{4}$	u+A <sub>11</sub> +B <sub>12</sub> = $13\frac{3}{4}$	u+A <sub>11</sub> +B <sub>22</sub> = $10\frac{3}{4}$		
	I <sub>1111</sub> = $-\frac{3}{4}$	I <sub>1112</sub> = $-\frac{3}{4}$	I <sub>1122</sub> = $9/4$		
A <sub>1</sub> A <sub>2</sub>	G <sub>1211</sub> = 13	G <sub>1212</sub> = 13	G <sub>1222</sub> = 13	G <sub>12..</sub> = 13	A <sub>12</sub> = $\frac{3}{4}$
	u+A <sub>12</sub> +B <sub>11</sub> = $13\frac{3}{4}$	u+A <sub>12</sub> +B <sub>12</sub> = $13\frac{3}{4}$	u+A <sub>12</sub> +B <sub>22</sub> = $10\frac{3}{4}$		
	I <sub>1211</sub> = $-\frac{3}{4}$	I <sub>1212</sub> = $-\frac{3}{4}$	I <sub>1222</sub> = $9/4$		
A <sub>2</sub> A <sub>2</sub>	G <sub>2211</sub> = 13	G <sub>2212</sub> = 13	G <sub>2222</sub> = 1	G <sub>22..</sub> = 10	A <sub>22</sub> = $-9/4$
	u+A <sub>22</sub> +B <sub>11</sub> = $10\frac{3}{4}$	u+A <sub>22</sub> +B <sub>21</sub> = $10\frac{3}{4}$	u+A <sub>22</sub> +B <sub>22</sub> = $7\frac{3}{4}$		
	I <sub>2211</sub> = $9/4$	I <sub>2212</sub> = $9/4$	I <sub>2222</sub> = $-27/4$		
G <sub>..kl</sub>	G <sub>..11</sub> = 13	G <sub>..12</sub> = 13	G <sub>..22</sub> = 10	$u = 12\frac{1}{4}$	
B <sub>kl</sub>	B <sub>11</sub> = $\frac{3}{4}$	B <sub>12</sub> = $\frac{3}{4}$	B <sub>22</sub> = $-9/4$		

# Why after so many cycles there is Va?

- Considering  $B_2B_2$  fixed,  $AA = Aa = 13$ , and  $aa = 10$
- $u = p^2G_{1122} + 2pqG_{1222} + q^2G_{2222}$
- $= \frac{1}{4}.13 + 2.\frac{1}{2}.\frac{1}{2}.13 + \frac{1}{4}.1 = 10$
- $A_iA_j$  effect
- $G_{22..} = 1$
- $A_{22} = G_{ij..} - u = 1 - 10 = -9$
- $I_{ijkl} = G_{ijkl} - (u + A_{ij} + B_{kl})$
- $I_{1111} = 13 - 10 - 3 + 0 = 0$
- Variances
- $Vg = \frac{1}{4}(13 - 10)^2 + 2.\frac{1}{2}.\frac{1}{2}(13 - 10)^2 + \frac{1}{4}(1 - 10)^2 = 27$
- $a = d = 6$
- $Va = 2pq[a + (p - q)d]^2 = 18 = 66.66\%$
- $Vd = (2pqd)^2 = 9 = 33.33\%$
- $Vi = Vg - Va - Vd = 0 = 0\%$

	$B_2B_2$	$G_{ij..}$	$A_{ij..}$
$A_1A_1$	$G_{1122} = 13$	$G_{11..} = 13$	$A_{11} = 3$
	$u + A_{11} + B_{22}$		
	$I_{1122} = 0$		
$A_1A_2$	$G_{1222} = 13$	$G_{12..} = 13$	$A_{12} = 3$
	$u + A_{12} + B_{22}$		
	$I_{1222} = 0$		
$A_2A_2$	$G_{2222} = 1$	$G_{22..} = 1$	$A_{22} = -9$
	$u + A_{22} + B_{22}$		
	$I_{2222} = 0$		
		$u = 10$	

# Main criteria to choose the breeding method

- Propagation system - *Sexual (cross-pollination or self-pollination) or clonal propagated*
- Trait - *Qualitative vs. Quantitative*
- Heritability - *Low or high*
- Genetic control - *Additive vs. non-additive*
- Proportion explored of the additive genetic variance – *Cov between evaluated and improved population*
- Resources available – *time, money, labor, ...*
- Product to be developed - *lines, hybrid, variety, etc.*

# How can we maximize the genetic gain per time?

- Increasing the intensity of selection ( $i$ )
- Minimizing the environment effect – **replicates and randomize**
- Increasing the genetic variability
- **Using more accurate or less time-consuming breeding schemes**
- *For instance, combining GS and HTP*
- Maximizing the additive genetic covariance between evaluated and improved population
- **c** = pathway between the unit of selection (US) and improved population ( $Y_M$ ) – **indirect selection**

$$RS(us, Ym) = i \frac{\sigma_{GYm}^2}{\sigma_{PYm}} \cdot \frac{COV_{G(us,Ym)}}{\sigma_{GYm}^2} \quad RS = i \frac{COV_{G(us,Ym)}}{\sigma_{PYm}} \quad RS = i \frac{r_{g(us,Ym)} \sigma_{a(us)} \sigma_{a(Ym)}}{\sigma_{PYm}} \quad RS = i \cdot c \cdot \frac{\sigma_a^2}{\sigma_{PYm}}$$

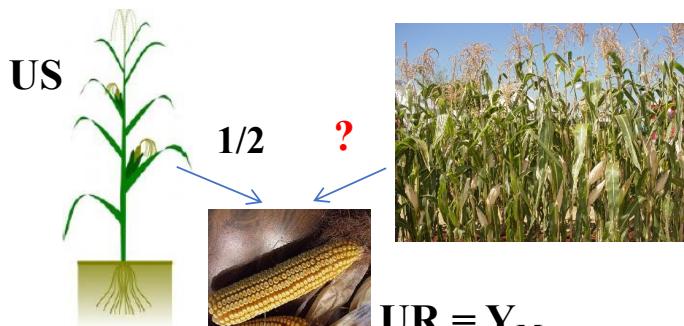
$$RS = i \cdot r_{aP} \cdot \sigma_a / T$$

$$r_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} = \frac{\sigma_a^2}{\sigma_a \sigma_P} = \frac{\sigma_a}{\sigma_P}$$

$$RS = i \frac{\sigma_a}{\sigma_P} \cdot \sigma_a \quad RS = i \frac{\sigma_a^2}{\sigma_P}$$

# Massal selection

- Harvest together similar and superior phenotypes
- They will form the newest improved population
- Only one sex (**female**)



- Little gains
- Easy, cheap, and no time-consuming
- Species little improved and high heritable traits

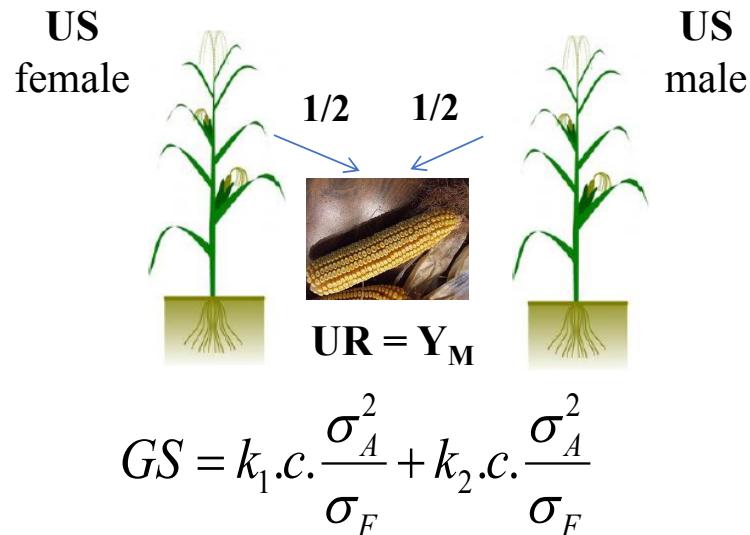
$$GS = k.c. \frac{\sigma_A^2}{\sigma_F} \quad k = i$$

$$GS = k. \frac{1}{2}. \frac{\sigma_A^2}{\sigma_F}$$

$$\sigma_F^2 = \sigma_G^2 + \sigma_E^2 + 2COV_{GE}$$

# Massal selection

- Both parents



$$GS = k_1 \cdot \frac{1}{2} \cdot \frac{\sigma_A^2}{\sigma_F} + k_2 \cdot \frac{1}{2} \cdot \frac{\sigma_A^2}{\sigma_F}$$

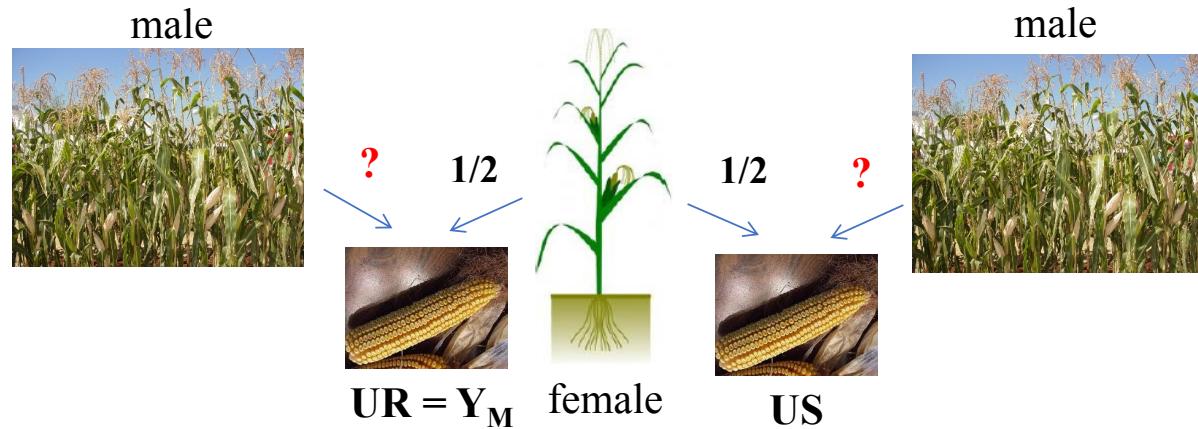
$$k_1 = k_2 \quad GS = k \frac{\sigma_A^2}{\sigma_F}$$

$$\sigma_F^2 = \sigma_G^2 + \sigma_E^2 + 2COV_{GE}$$

- Better gains but still low

# Selection based on progenies

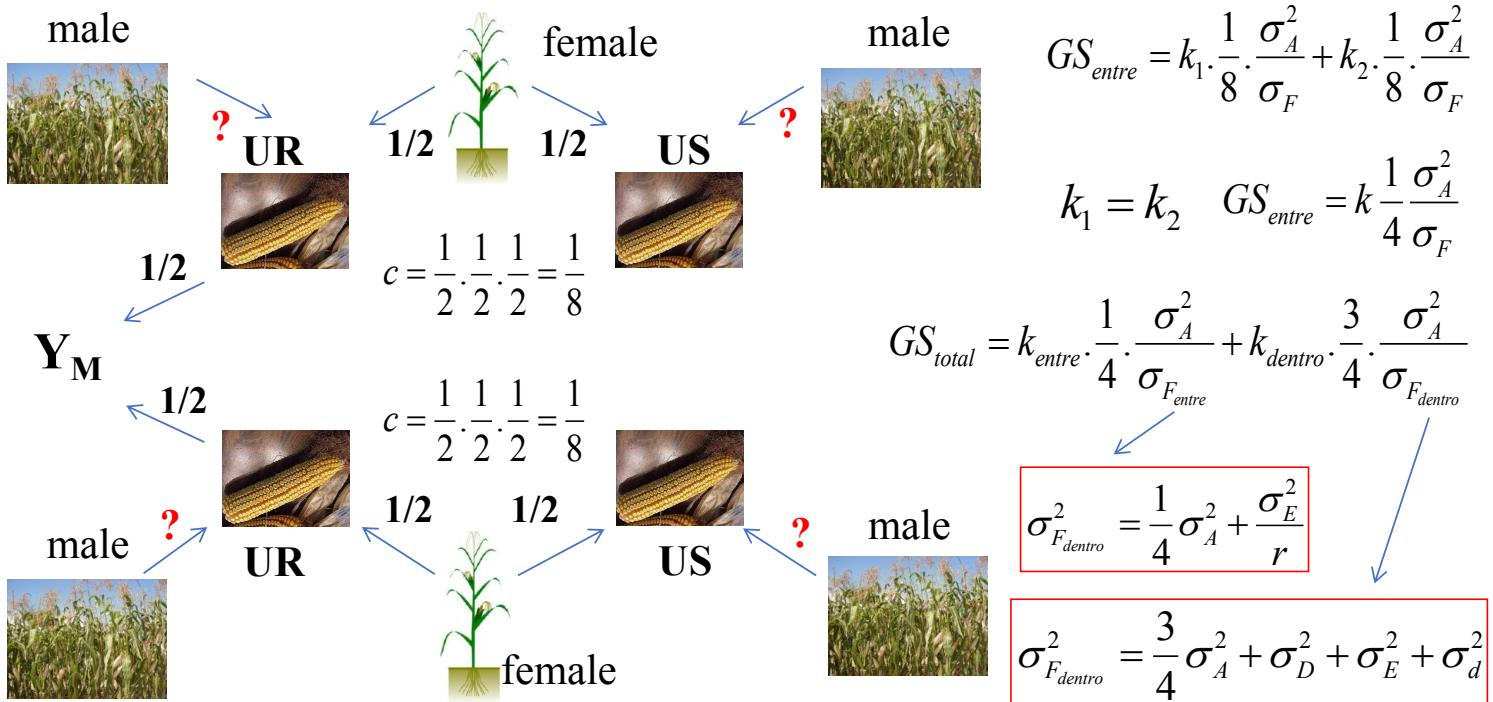
- Among half-sibs (**only one sex**)



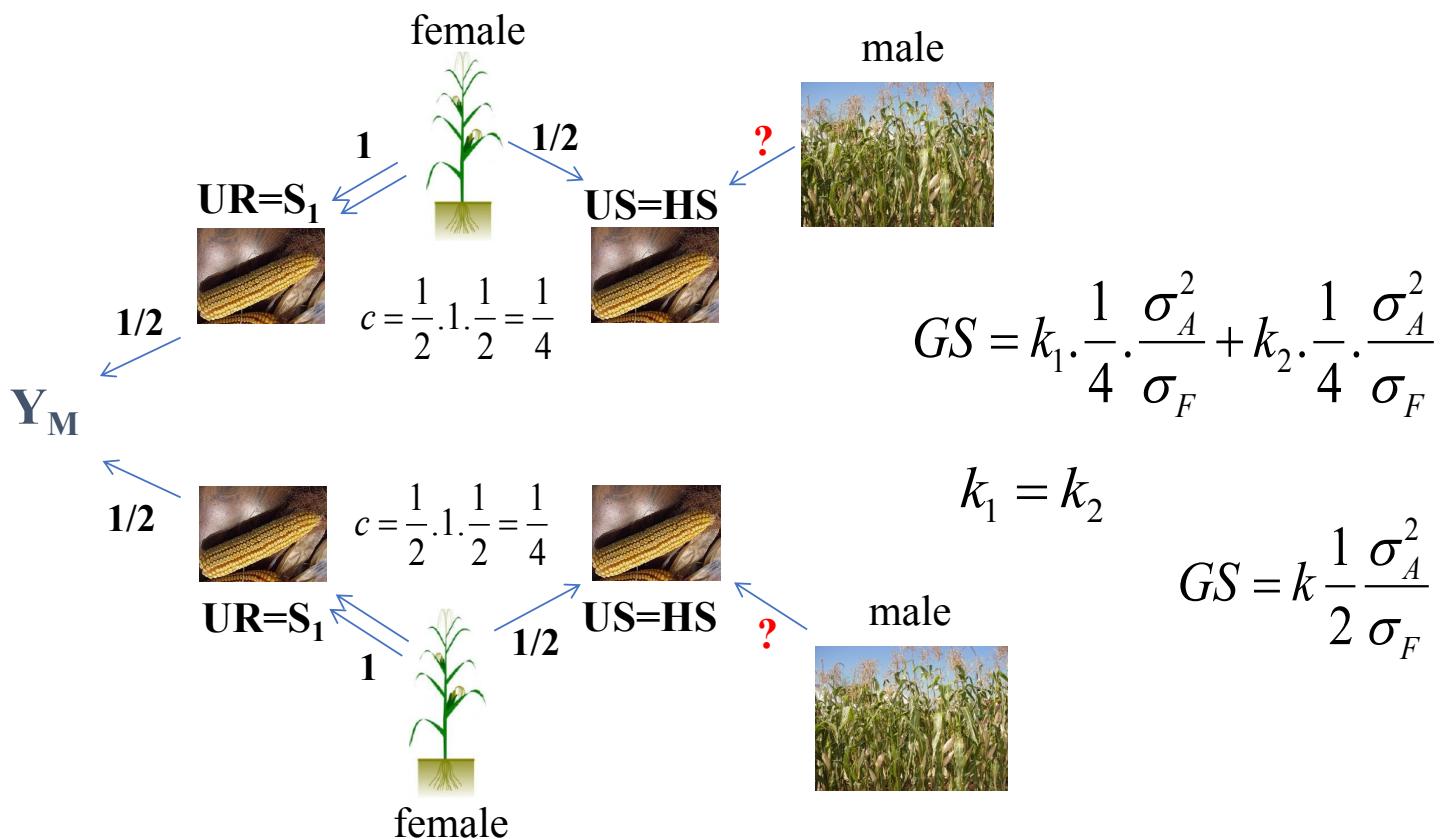
$$c = \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{4} \quad GS = k \cdot \frac{1}{4} \cdot \frac{\sigma_A^2}{\sigma_F}$$

# Selection based on progenies

- Half-sibs but in both parents



## Recurrent selection – HS / S<sub>1</sub>



# Comparison between breeding methods

- Response to selection per time

$$RS = \frac{i \cdot r_{aP} \cdot \sigma_a}{T} \quad EF_{X/Y} = \frac{RS_X \cdot T_Y}{RS_Y \cdot T_X} \cdot 100$$

- It is possible simulate innumEROUS breeding schemes
- There is no “the best method”