Impacts of Genotype-by-Environment Interaction on across-Environment Genomic Evaluation and Joint Selection of Bulls

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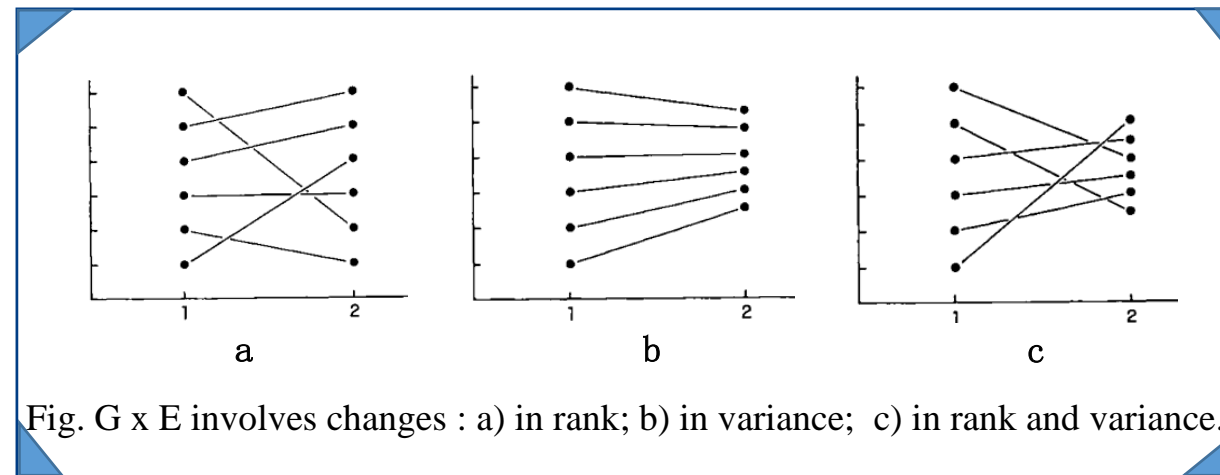27 NOVEMBER 2018 | PHD STUDENT

$$P = G + E + G \times E$$

Fig. G x E involves changes : a) in rank; b) in variance; c) in rank and variance.
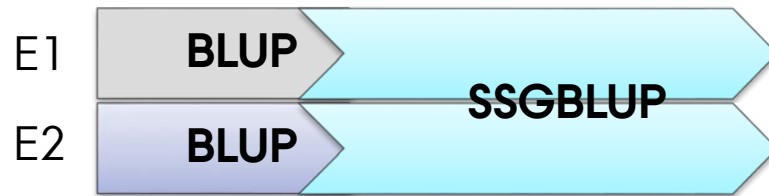
(J. C. Bowman, 1972)

Reranking $\Rightarrow r_g < 1$

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"*Imagine if...*"

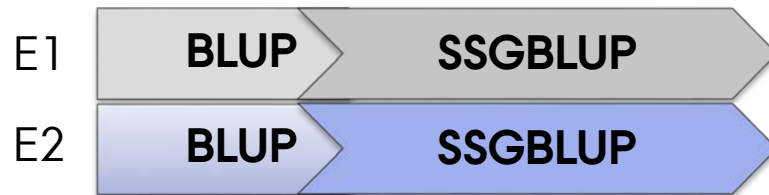2 environments both select for MY with $r_{g(MY_1, MY_2)}$ less than 1

☐ 3 solutions (generation 6-20)

AG-J (Basic solution)

WG-W

AT-J

Across-environment **G**enomic evaluation

& **J**oint selection of bulls   (Coop, GS)

Within-environment **G**enomic evaluation

& **W**ithin-environment selection of bulls

   (Non-coop, GS)

Across-environment **T**raditional evaluation

& **J**oint selection of bulls   (Coop, non GS)

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M & M

$$\begin{bmatrix} \mathbf{y_1} \\ \mathbf{y_2} \end{bmatrix} = \begin{bmatrix} \mathbf{X_1} & \mathbf{0} \\ \mathbf{0} & \mathbf{X_2} \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta_1} \\ \boldsymbol{\beta_2} \end{bmatrix} + \begin{bmatrix} \mathbf{Z_1} & \mathbf{0} \\ \mathbf{0} & \mathbf{Z_2} \end{bmatrix} \begin{bmatrix} \mathbf{a_1} \\ \mathbf{a_2} \end{bmatrix} + \begin{bmatrix} \mathbf{e_1} \\ \mathbf{e_2} \end{bmatrix}$$

☐ Individual evaluation

$\mathbf{y_i}$: vector of observations of ith trait, i=1, 2

$\boldsymbol{\beta_i}$: vector of herd-year-season fixed effects in ith environment

$\mathbf{a_i}$: vector of additive genetic effects of ith trait

$\mathbf{e_i}$: vector of residual effects of ith trait

$\mathbf{X_i}$ and $\mathbf{Z_i}$: incidence matrices connecting $\boldsymbol{\beta_i}$ and $\mathbf{a_i}$ to y_i, respectively.

$$\begin{bmatrix} \mathbf{a_1} \\ \mathbf{a_2} \end{bmatrix} \sim N\left(0, \begin{bmatrix} \sigma_{a_1}^2 & r_g \sigma_{a_1} \sigma_{a_2} \\ & \sigma_{a_2}^2 \end{bmatrix} \otimes \mathbf{H}\right), \quad \begin{bmatrix} \mathbf{e_1} \\ \mathbf{e_2} \end{bmatrix} \sim N\left(0, \begin{bmatrix} \sigma_{e_1}^2 & 0 \\ & \sigma_{e_2}^2 \end{bmatrix} \otimes \mathbf{I}\right)$$

☐ Linkage disequilibrium (LD) $\mathbf{H}$: matrix of additive genetic relationships among pedigree individuals (BLUP),

unified genetic relationship matrix of all genotyped and non-genotyped animals (ssGBL

2,000 QTL , 40,000 markers
(randomly distributed among 30 chromosomes of 100 cM each)

Danish Red Dairy Cattle
(incl. 6,581 animals with 43,621 markers)

M & M

ADAM

Program to simulate selective-breeding schemes for animals and plants

Developers

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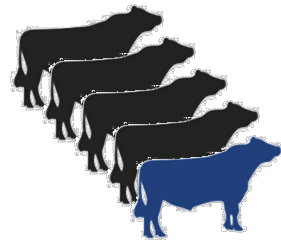Axeltorv 3
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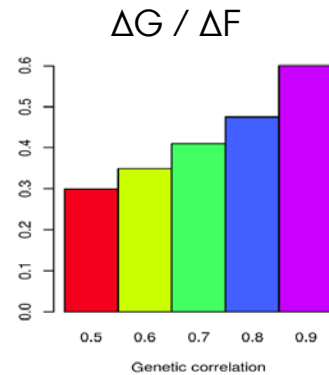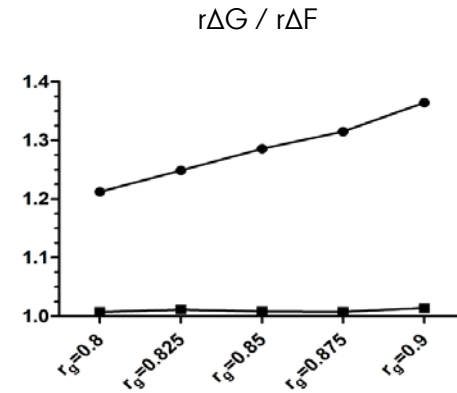
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☐ Analysis

rΔG / rΔF

ΔG / ΔF

Relative ΔG/ΔF (rΔG/rΔF)

Proportion of foreign sires

Absolute ΔG/ΔF∗

Inclination for cooperation

Profitability of cooperation

(∗ΔF based on 6000 IBD loci)

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RESULTS & DISCUSSIONS-EPS*
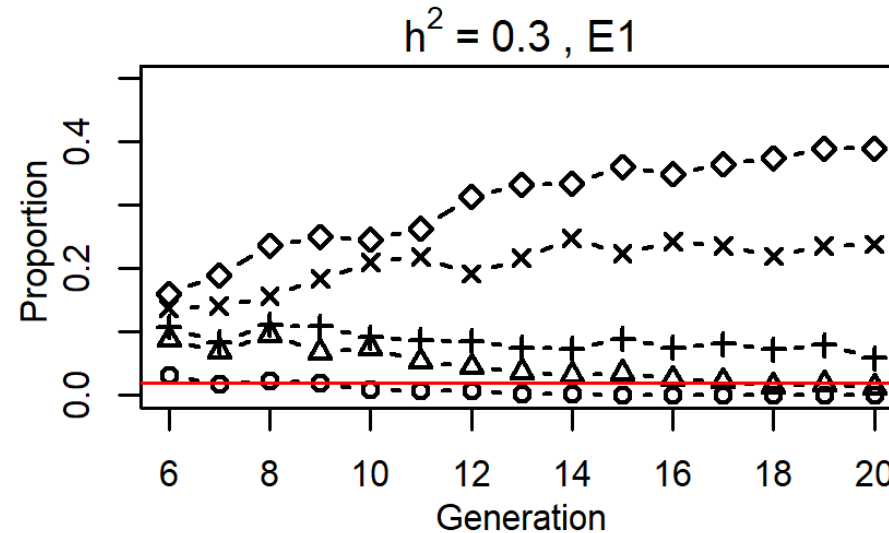
☐ Proportion of foreign sires in AG-J

(* **E**qual **P**opulation **S**izes: select **50 ♂ 1000 ♀** /generation$_{6\text{-}20}$)

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RESULTS & DISCUSSIONS-EPS

☐ Proportion of foreign sires in AG-J

➢ 0 ~ 42.6%

➢ Higher r_g, weaker GxE, more foreigners

➢ $r_g < 0.85$~0.875, coop diverged

$r_g > 0.85$~0.875, long-term coop

" split-point " r_g: **0.85~0.875**

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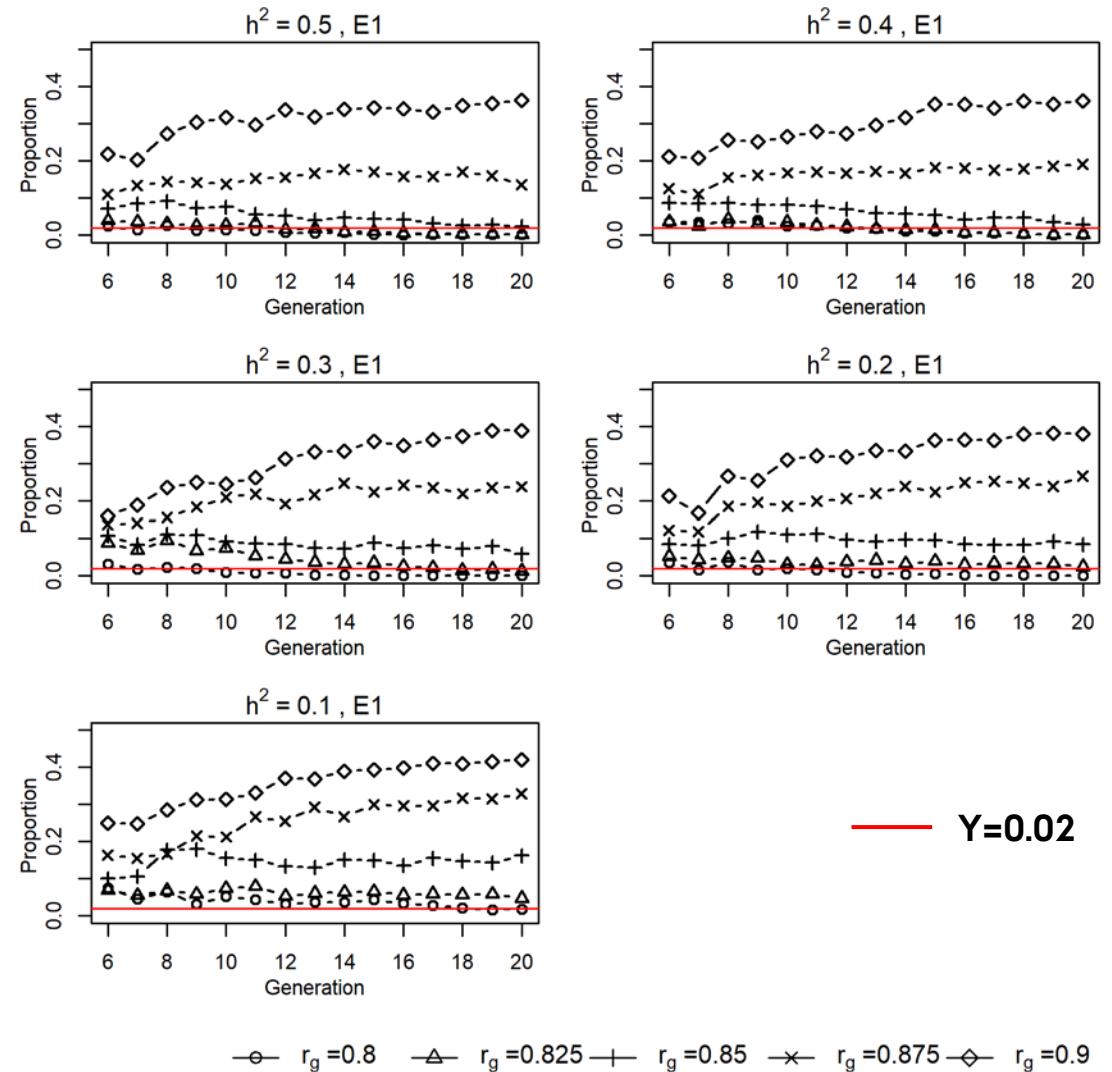
RESULTS & DISCUSSIONS-EPS

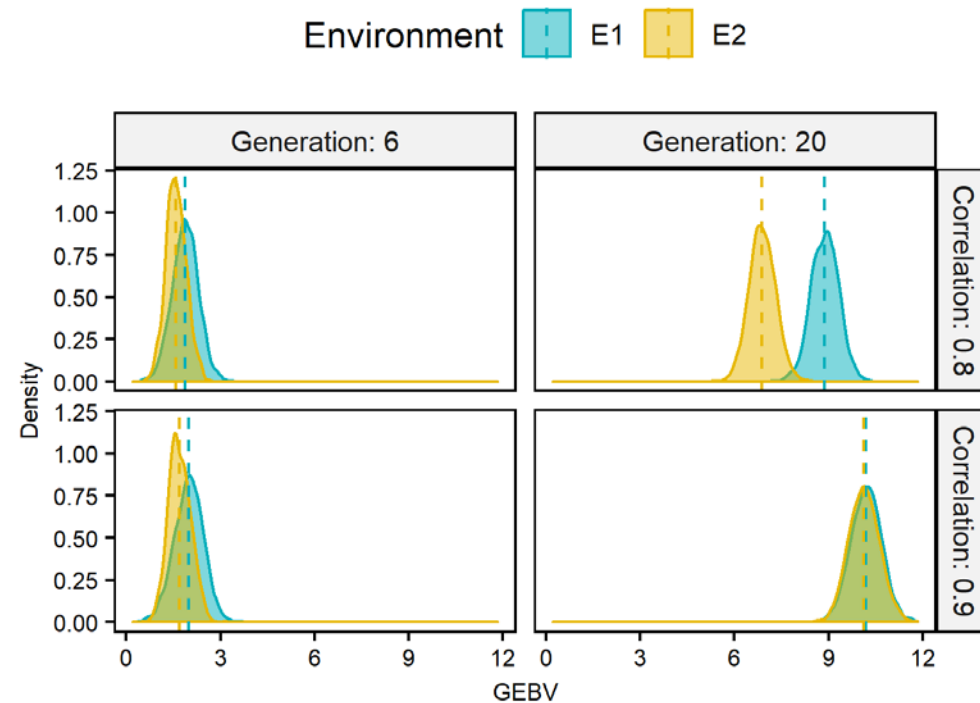☐ Illustration for " $split-point$ " r_g: $\mathbf{0.85 \sim 0.875}$ in AG-J

Fig. Distributions of male GEBVs for a randomly selected replicate in AG-J & EPS. (h²=0.3)

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☐ Understand " $split - point$ " r_g: $\mathbf{0.85} \sim \mathbf{0.875}$ in AG-J

Increased difference of genetic levels

r_g

Increased variations of GEBVs of candidates

" $spliting\text{-}point$ " r_g

$r_g = 0$ $r_g = 1$

Divergence Convergence

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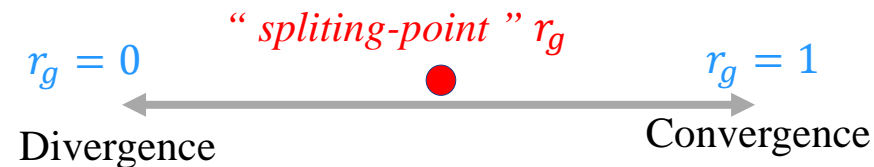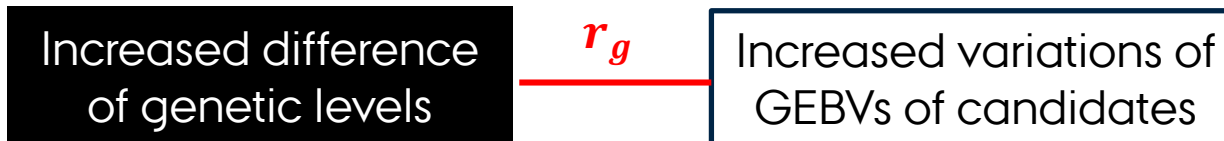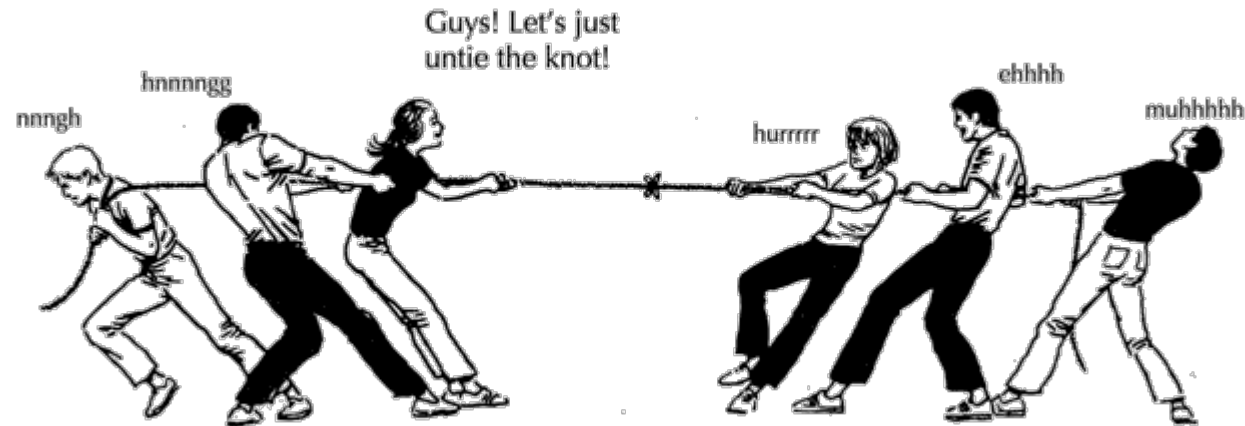
RESULTS & DISCUSSIONS-EPS

☐ " $split-point$ " r_g in AT-J: > 0.9

AG-J: $0.85 \sim 0.875$

More opportunities of utilizing G × E in the era of GS

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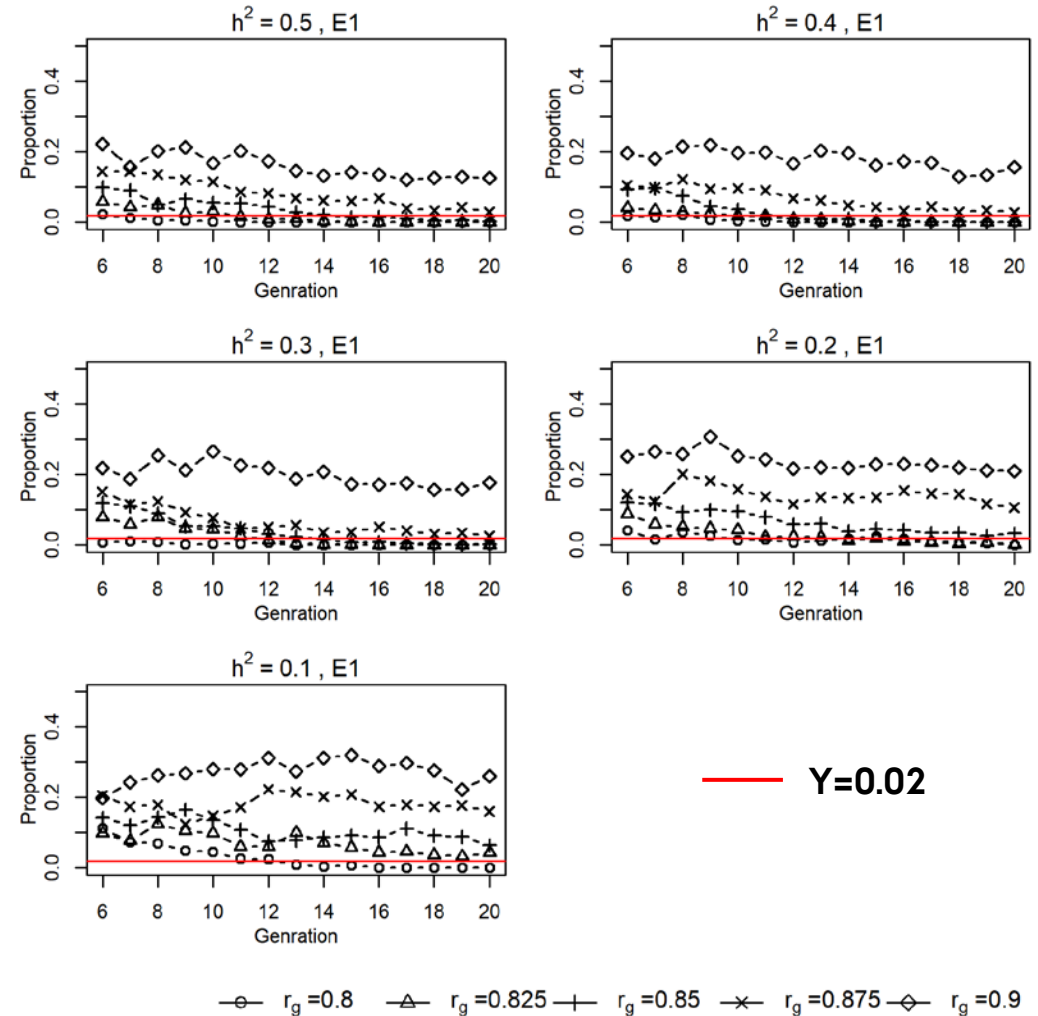
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RESULTS & DISCUSSIONS-EPS

☐ Absolute ΔG/ΔF in AG-J

➤ Higher r_g, higher ΔG

➤ "turning-point " r_g: 0.85~ 0.875

a.   ΔG (E1)

b.   ΔF (E1)

r_g=0.8   r_g=0.825   r_g=0.85   r_g=0.875   r_g=0.9

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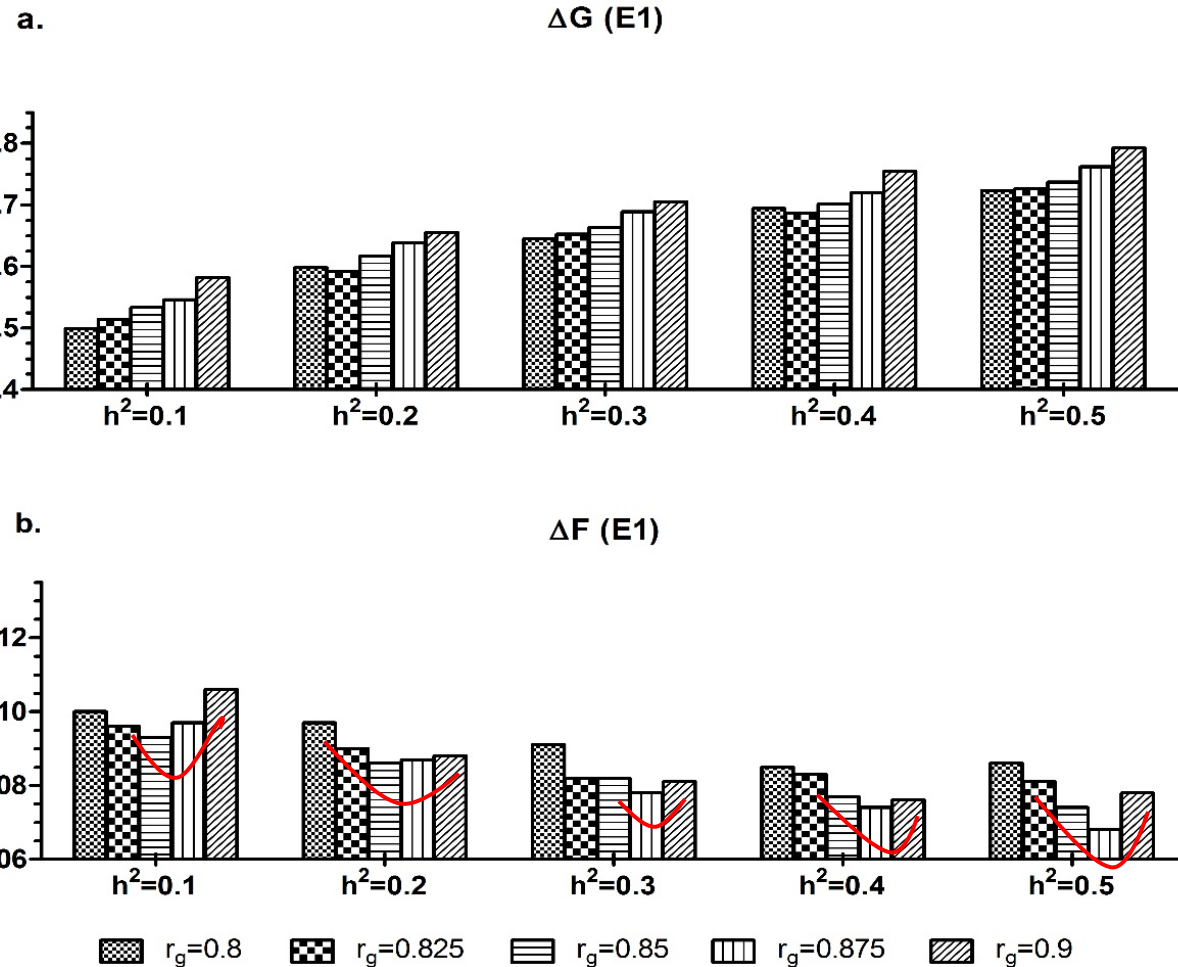
RESULTS & DISCUSSIONS-EPS

☐ Understand " $turning-point$ " r_g : $\mathbf{0.85 \sim 0.875}$ in AG-J

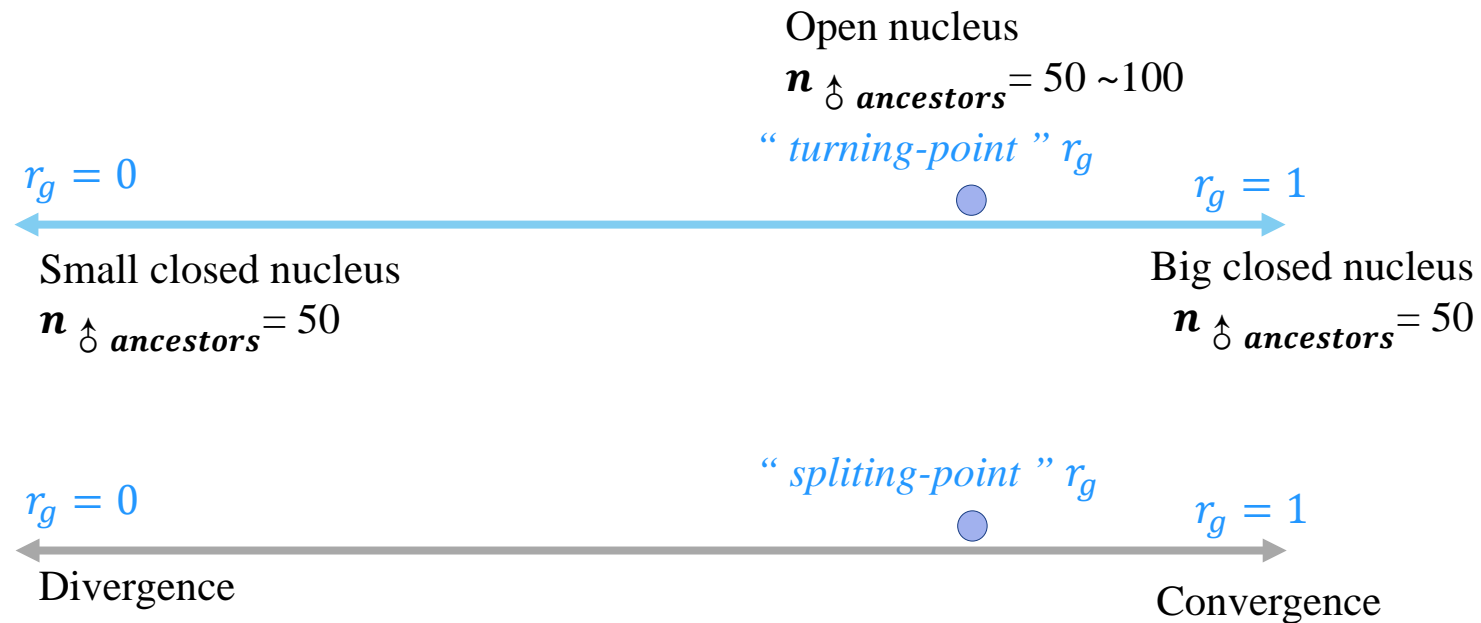$$\Delta F = 1/4\,(1-\alpha) \sum r_i^2$$

r_i: long-term genetic
contribution of ancestor i
α: constant departure
from H-W proportion

(Bijma P *et al.,* 2000)

r_g	Sex	Generation										
		20	**19**	**18**	**17**	**16**	**15**	**14**	**13**	**12**	**11**	**10**
0.8	♂	1500	50	50	50	50	50	50	50	50	49	50
	♀		1000	679	534	457	405	363	339	332	314	308
0.825	♂	1500	50	50	50	50	50	50	49	50	50	48
	♀		1000	683	536	456	408	360	331	301	292	290
0.85	♂	1500	50	50	50	50	50	50	49	50	50	50
	♀		1000	694	551	456	401	370	344	325	315	307
0.875	♂	1500	50	54	59	64	74	72	78	76	69	65
	♀		1000	707	580	503	475	463	454	456	446	444
0.9	♂	1500	50	54	55	55	57	59	59	62	59	59
	♀		1000	692	543	481	450	421	425	424	423	426

RESULTS & DISCUSSIONS-EPS

☐ Relative * ΔG/ΔF in AG-J

➢ rΔG >1: coop beneficial for genetic gain

➢ rΔF <1: coop beneficial for controling inbreeding

(* Relative to WG-W situation)

a. rΔG (E1)

b. rΔF (E1)

h²=0.1   h²=0.2   h²=0.3   h²=0.4   h²=0.5

RESULTS & DISCUSSIONS-UPS*

☐ Proportion of foreign sires in AG-J

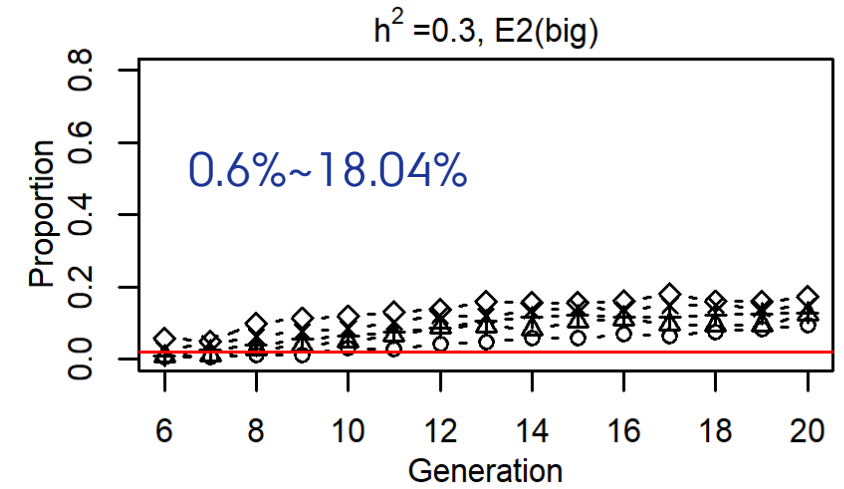➢ E1 (Small) more inclined
to coop, drives the
participation of E2 (big)

$h^2 = 0.3$, E1(small)

$h^2 = 0.3$, E2(big)

23.96% ~76.6%

0.6%~18.04%
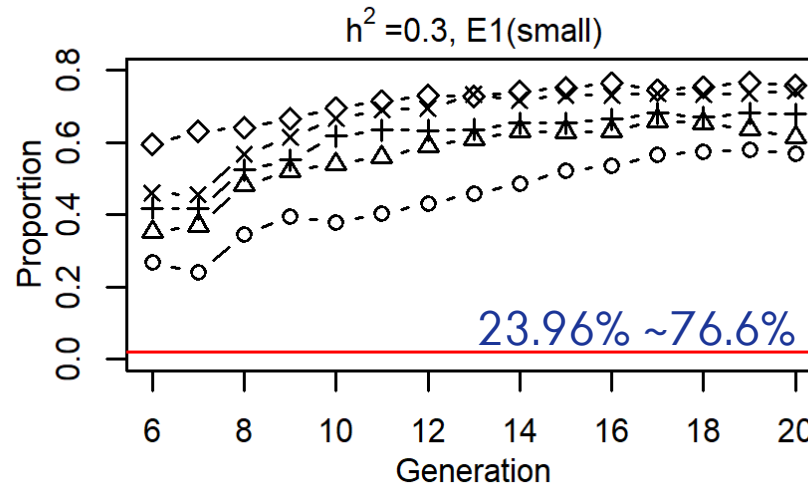
—○— $r_g = 0.8$ —△— $r_g = 0.825$ —+— $r_g = 0.85$ —✕— $r_g = 0.875$ —◇— $r_g = 0.9$ —— **Y=0.02**

(* **U**nequal **P**opulation **S**izes: E1 select **50 ♂ 400 ♀** /generation$_{6-20}$
E2 select **50 ♂ 1600 ♀** /generation$_{6-20}$)

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RESULTS & DISCUSSIONS-UPS

☐ "$split-point$"r_g in AG-J

➤ Approx 0.7, lower than EPS,
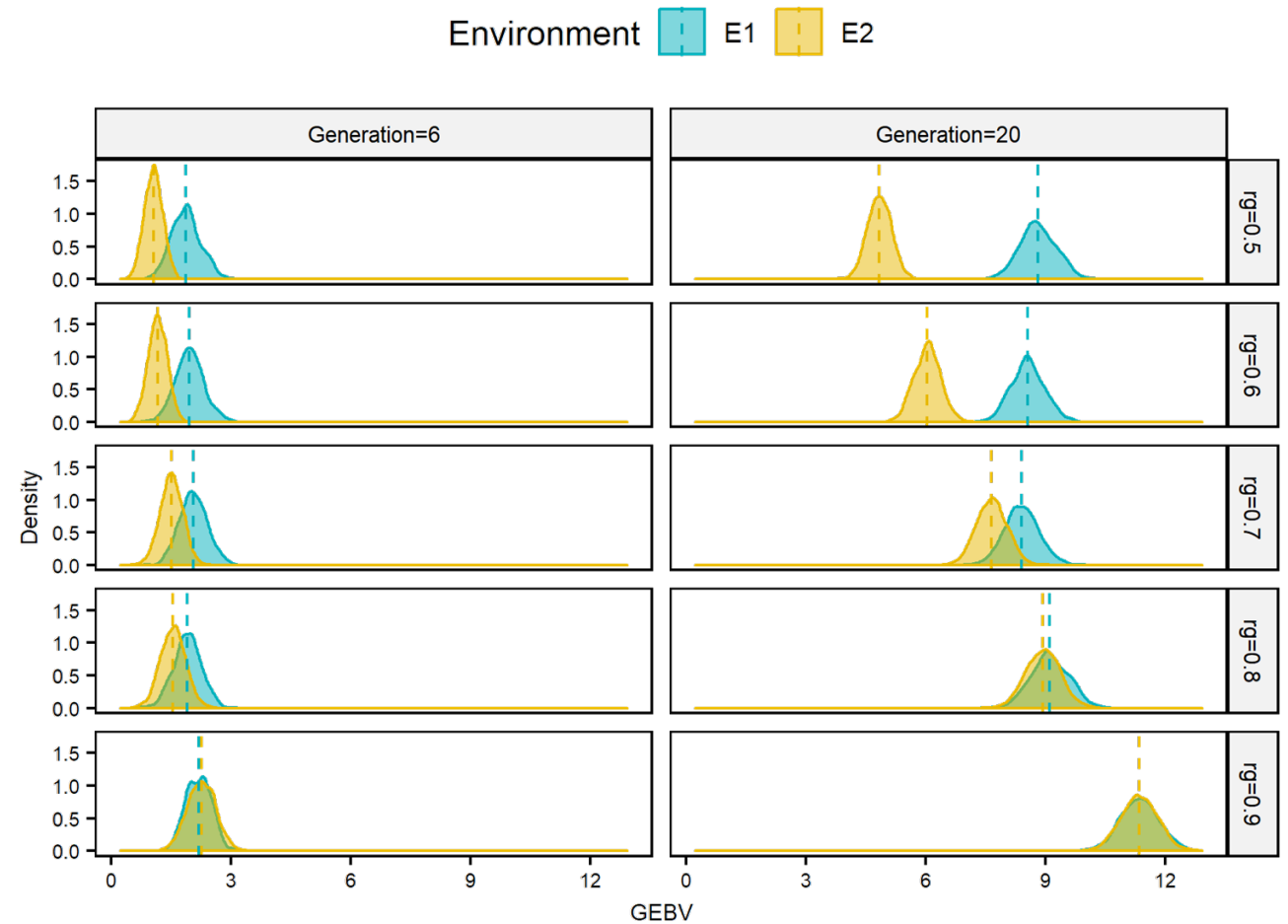
Long-term coop of UPS allowed lower r_g

Fig. Distributions of male GEBVs for a randomly selected replicate in AG-J & UPS. (h²=0.3)

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RESULTS & DISCUSSIONS-UPS

☐ Absolute ΔG/ΔF in AG-J

➢ ΔG increased as r_g increased,

   E1 (small), larger increment: preference for coop

   E2 (big), larger ΔG : self-advantage

	ΔG	
	E1	E2
r_g=0.8	0.62	0.74
r_g=0.825	0.63	0.74
r_g=0.85	0.67	0.75
r_g=0.875	0.68	0.75
r_g=0.9	0.71	0.76

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RESULTS & DISCUSSIONS-UPS

☐ Relative ΔG/ΔF in AG-J

➢ Coop beneficial to ΔG/ΔF

➢ E1 (small), larger increment: preference for coop

	rΔG		rΔF	
	E1	E2	E1	E2
r_g=0.8	1.33	1.02	0.78	0.96
r_g=0.825	1.36	1.02	0.96	0.97
r_g=0.85	1.43	1.03	1.00	0.95
r_g=0.875	1.46	1.03	1.08	0.94
r_g=0.9	1.52	1.04	1.04	0.97

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CONCLUSIONS

opportunity of accounting for G x E

➢ For EPS*, $r_g < 0.8$, little possibility in coop; $r_g < 0.85$~0.875, short-term coop; $r_g > 0.85$~0.875, long-term coop possible

➢ For UPS, smaller environment more inclined to coop; long-term coop allowed at lower r_g

➢ Coop in favor of genetic gain and controlling inbreeding

➢ More opportunities of utilizing G × E in the era of GS

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Thanks for listening & questions

(http://www.nordicebv.info/)