Trade-off between fertility and production in French dairy cattle in the context of climate change

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Context

- Climate change will lead to higher average temperatures and more frequent extreme events
- High temperatures has ***negative effect on all cattle performances*** (production, fitness)
- Essential to identify animals able to **achieve sufficient overall production** while maintaining their **reproductivity ability** in environments with increasing temperatures

Objectives

1. Study ***trade-offs*** between production and fertility under different climate conditions
2. Predict the ***effects of current selection*** on the future performances, under warmer climate
3. Define ways to select ***heat tolerant animals***

Data

10 years of data (2010-2020)
Records from **first lactation**

Production

Protein yield (PY)

Test-day performances records

Restricted to 80 and 200 days in milk to avoid taking into account the G x lactation stage interaction

Fertility

Conception rate, 1st insemination (CR)

1 if succes (calving); 0 otherwise

Inseminations between 50 and 180 days after calving
(= more than 90% of the first service records for both breeds)

Holstein		Montbeliarde
3,251,061	**Number of cows with PY and CR**	**612,299**
10,245,692	Number of records of PY	1,966,985
3,351,068	Number of records of CR	649,814
5463	**Number of sires**	**1612**

Data

Production

Protein yield (PY)

Test-day performances records

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Fertility

Conception rate, 1st insemination (CR)

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Inseminations between 50 and 180 days after calving
(= more than 90% of the first service records for both breeds)

Meteorological data

Daily estimated temperature and humidity
on a grid of 9892 squares of 8x8km

$$\mathbf{THI} = (1.8 \times \mathbf{T} + 32) - (0.55 - 0.0055 \times \mathbf{RH}) \times (1.8 \times \mathbf{T} - 26)$$

AGROCLIM, INRAE

Data

Production

THIp

= average THI over a ***3d period <u>before</u> TD***

(the date of the TD and the 2 previous days)

Fertility

THIf

= average THI over a ***8d period <u>after</u> service***

(day of insemination to day 7 after insem.)

Meteorological data

Daily estimated temperature and humidity

on a grid of 9892 squares of 8x8km

$$\mathbf{THI} = (1.8 \times \mathbf{T} + 32) - (0.55 - 0.0055 \times \mathbf{RH}) \times (1.8 \times \mathbf{T} - 26)$$

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Data

Production

THIp

= average THI over a ***3d period before TD***

(the date of the TD and the 2 previous days)

Fertility

THIf

= average THI over a ***8d period after service***

(day of insemination to day 7 after insem.)

Meteorological data

THI Min-Max = 11-79

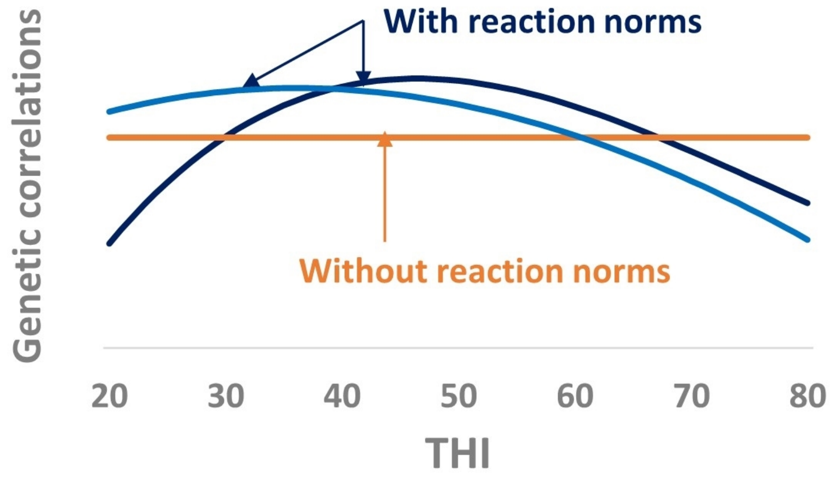
	Holstein	Montbeliarde
Average THIp (PY)	51.3	47.4
Average THIf (CR)	50.7	47.3

About 1.5% performances recorded at THI>70

Model

- **Bivariate reaction norm models (= account for GxTHI)**

  Trends in genetic correlations between production and fertility traits **over a range of THI conditions**



- **Sire models**

  As CR has a very low genetic variance, very large datasets are required for **accurate estimation** of variances and within/between traits covariances.

  Sire models make it possible to handle very large datasets spanning all THI conditions.

  Only one performance per cow for CR

  ⇨ sire models appropriate for describing the effect of the THI gradient

Model

fertility →
production →

$$\begin{bmatrix} y_f \\ \\ y_p \end{bmatrix} = \begin{bmatrix} X_f\beta_f + Z_f a_f + e_f \\ \\ X_p\beta_p + Z_p a_p + W_p p_p + e_p \end{bmatrix}$$

Model

fertility → y_f

production → y_p

$$\begin{bmatrix} y_f \\ y_p \end{bmatrix} = \begin{bmatrix} X_f \boldsymbol{\beta_f} + Z_f a_f + e_f \\ X_p \boldsymbol{\beta_p} + Z_p a_p + W_p p_p + e_p \end{bmatrix}$$

$\boldsymbol{\beta_f}$ and $\boldsymbol{\beta_p}$: **fixed effects**, specific to each trait

Model

$$\begin{matrix} \text{fertility} \longrightarrow \\ \\ \text{production} \longrightarrow \end{matrix} \begin{bmatrix} y_f \\ \\ y_p \end{bmatrix} = \begin{bmatrix} X_f\beta_f + Z_f\boldsymbol{a_f} + e_f \\ \\ X_p\beta_p + Z_p\boldsymbol{a_p} + W_p p_p + e_p \end{bmatrix}$$

Vectors of **additive sire regression coefficients**

a_f: for fertility, 3 values per animal (Legendre order 0 to 2)

a_p: for production, 4 values per animal (Legendre order 0 to 3)

Model

fertility → $\begin{bmatrix} y_f \\ \\ y_p \end{bmatrix} = \begin{bmatrix} X_f\beta_f + Z_f\boldsymbol{a_f} + e_f \\ \\ X_p\beta_p + Z_p\boldsymbol{a_p} + W_p\boldsymbol{p_p} + e_p \end{bmatrix}$ ← production

Vectors of **additive sire regression coefficients**

a_f: for fertility, 3 values per animal (Legendre order 0 to 2)

a_p: for production, 4 values per animal (Legendre order 0 to 3)

p_p: vector of permanent environment regression coefficients **for production**, 4 values modeled with the same polynomials as those used for the additive effect of the sire

Model

$$\begin{bmatrix} y_f \\ \\ y_p \end{bmatrix} = \begin{bmatrix} X_f\beta_f + Z_f a_f + \boldsymbol{e_f} \\ \\ X_p\beta_p + Z_p a_p + W_p p_p + \boldsymbol{e_p} \end{bmatrix}$$

fertility → y_f

production → y_p

e_f and e_p: vectors of **residual variances**

considered **heterogeneous across 5 THIp/f classes** (≤ 29, 30-39, 40-49, 50-59, ≥ 60)

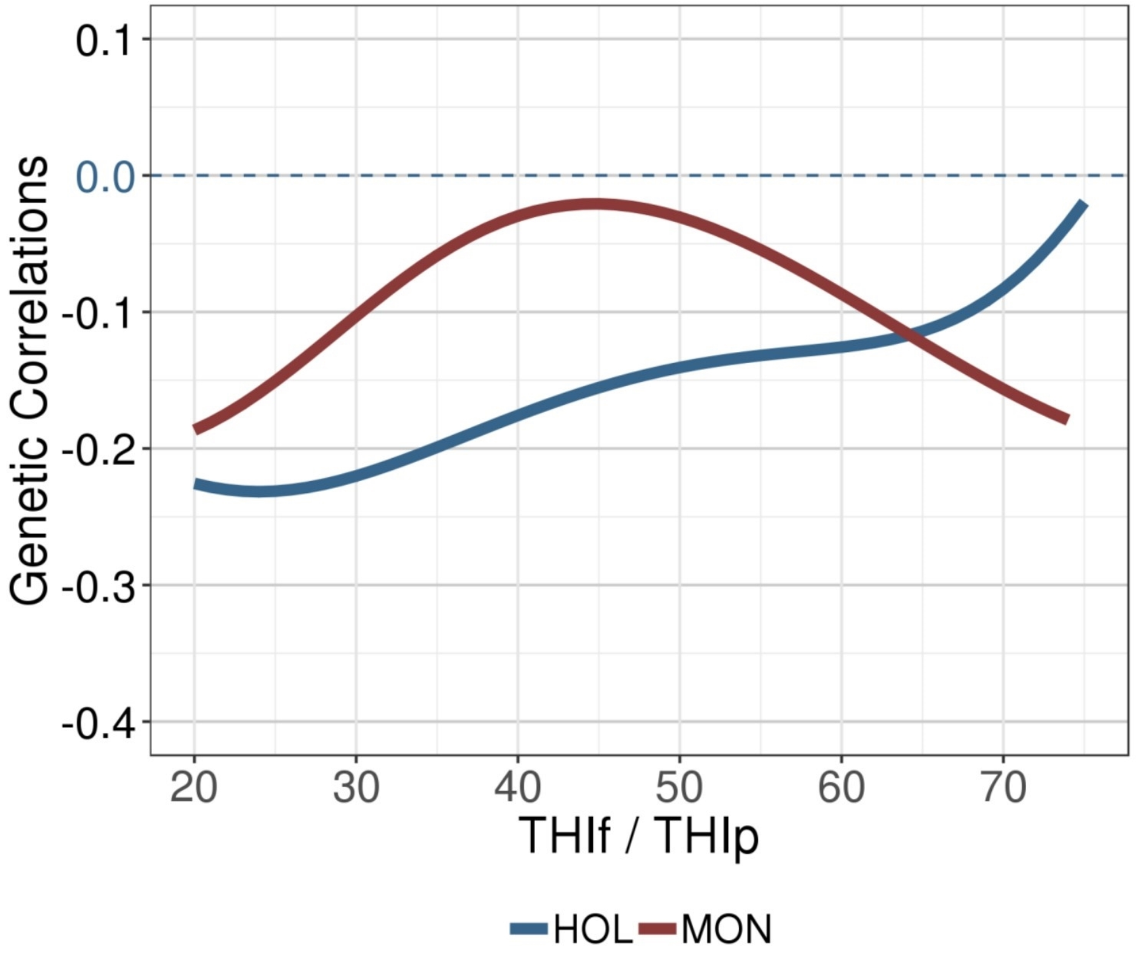
1

Trade-offs under different climate conditions

Results – Trade-offs under different climate conditions

Context
Objective
Data
Model
Results
Summary

Genetic correlations between CR and PY along THI gradient, considering an **equivalent THI for both traits (THIf = THIp)**



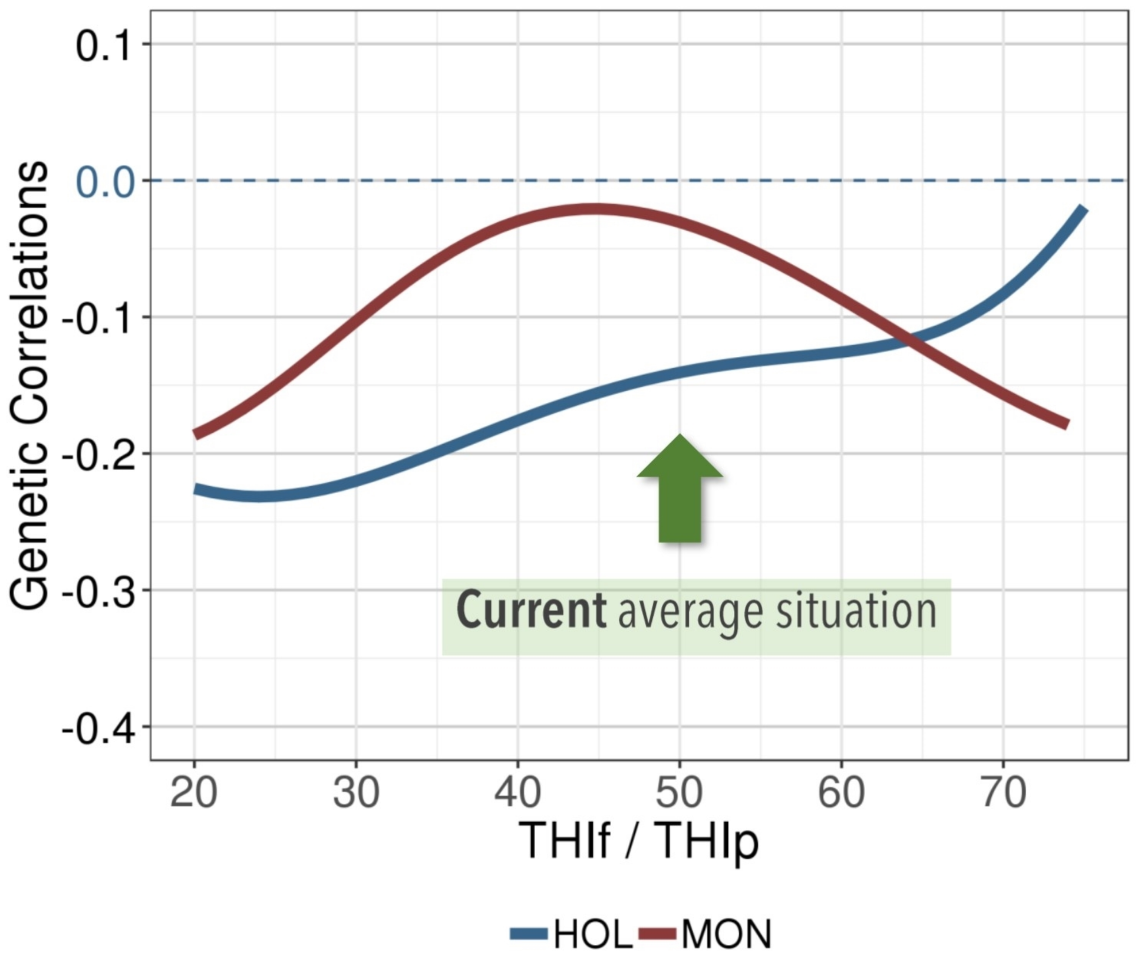
Low to moderate genetic correlations between CR and PY

↕

mid-lactation PY

Results – Trade-offs under different climate conditions

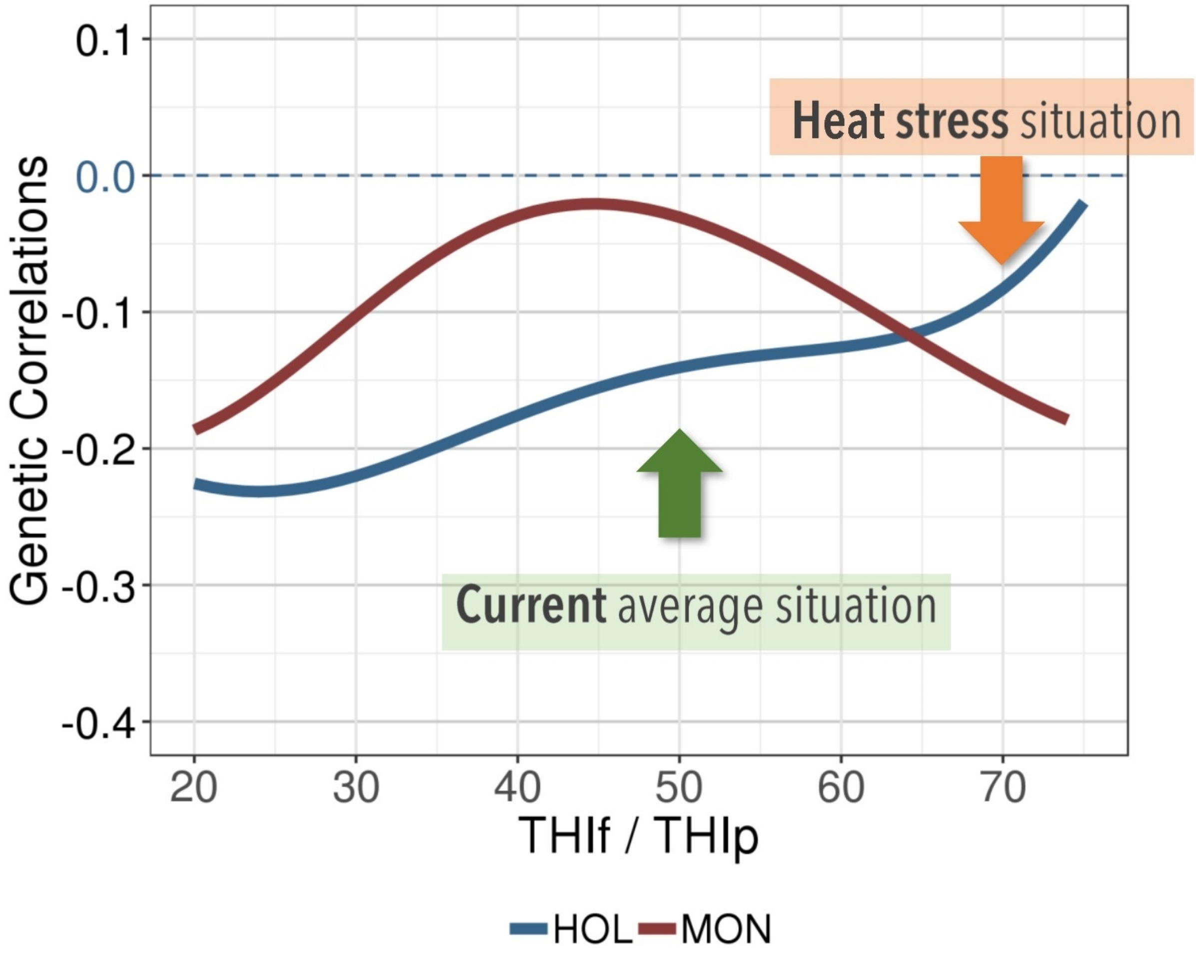
Genetic correlations between CR and PY along THI gradient, considering an **equivalent THI for both traits (THIf = THIp)**



Current genetic correlation between CR and PY (-0.14 for HOL; -0.03 for MON)

Results – Trade-offs under different climate conditions

Genetic correlations between CR and PY along THI gradient, considering an **equivalent THI for both traits (THIf = THIp)**



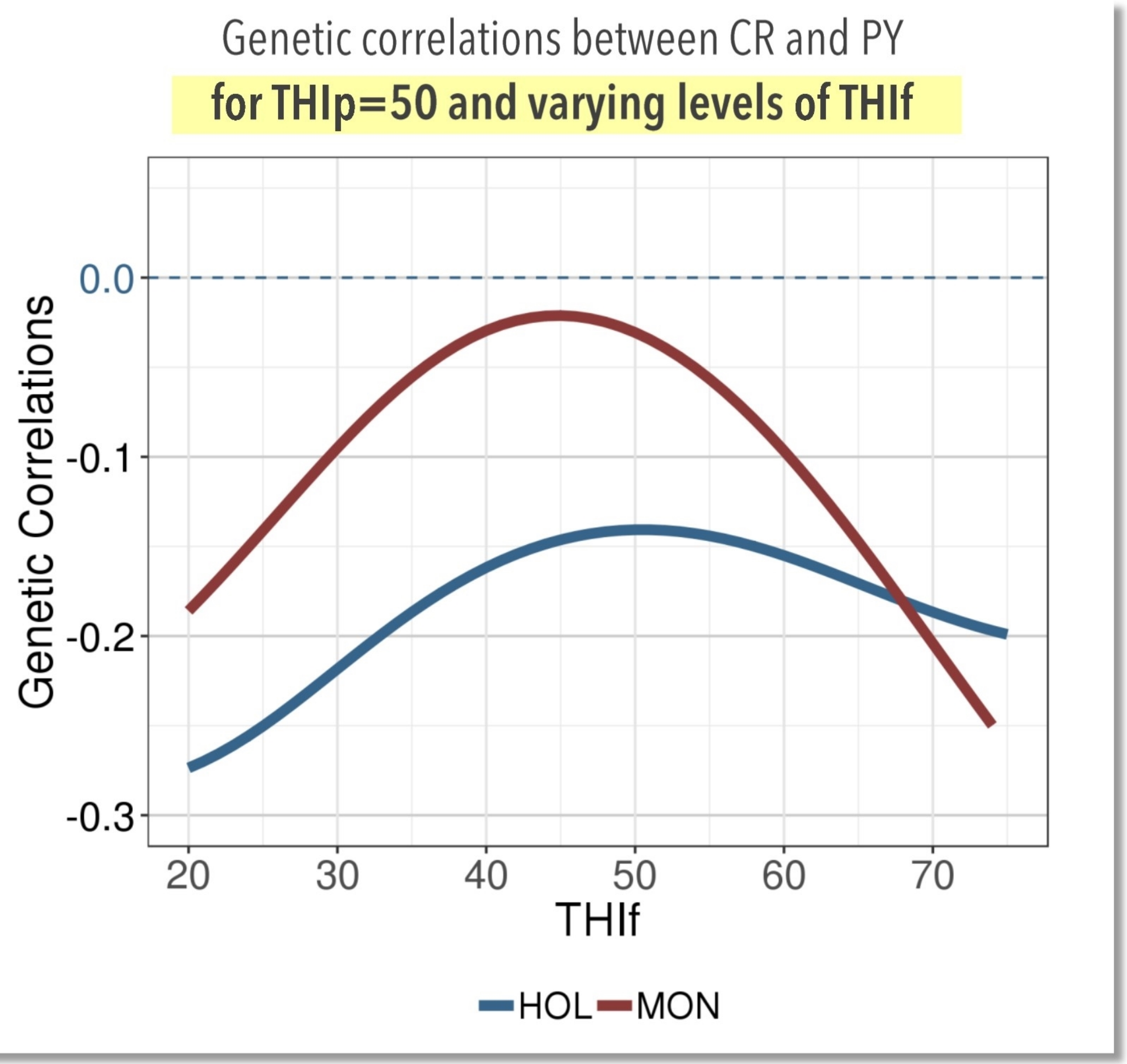
Genetic correlation between CR and PY for **heat stress scenario** (-0.08 for HOL; -0.16 for MON)

Current genetic correlation between CR and PY (-0.14 for HOL; -0.03 for MON)

2

Predict the ***effects of current selection*** on the future performances, under warmer climate

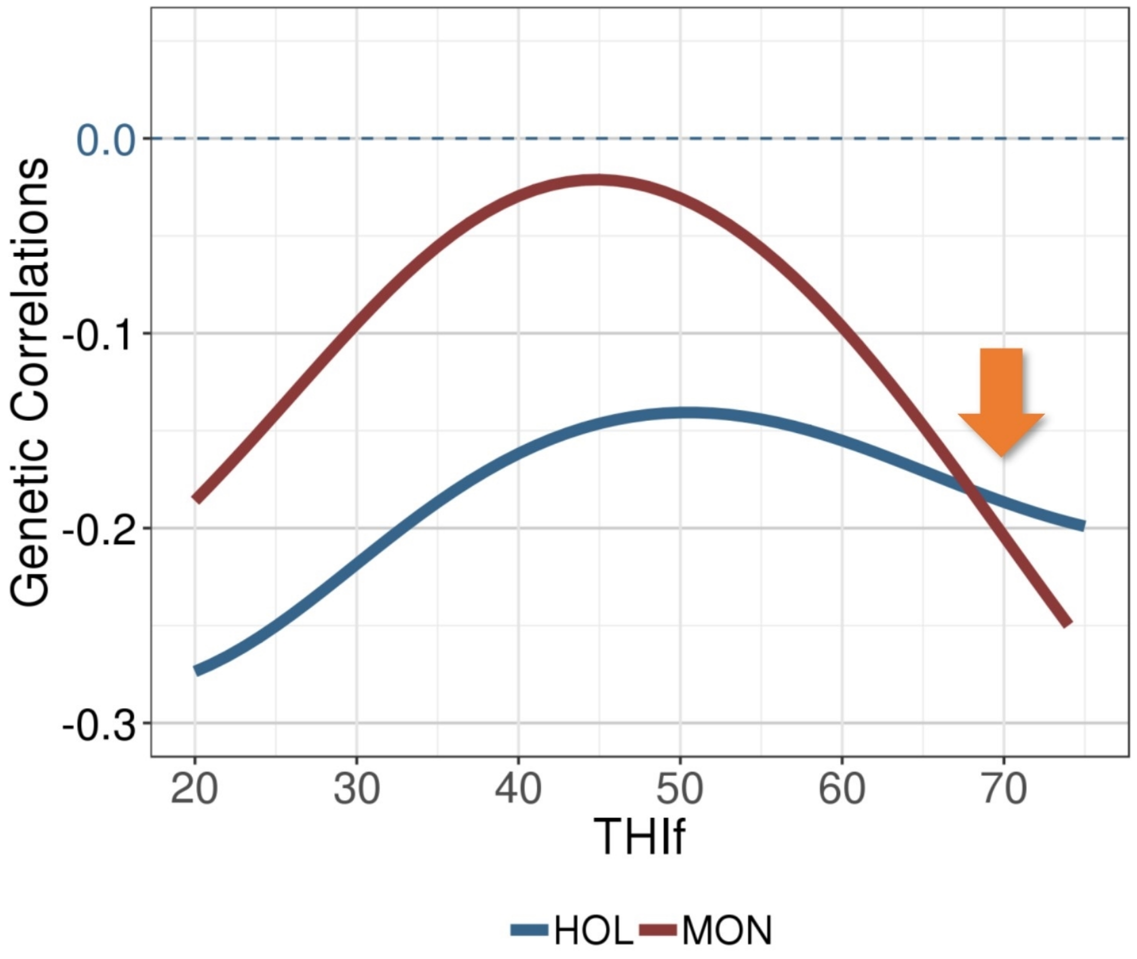
Results – Predict effects of current selection



Results – Predict effects of current selection

Genetic correlations between CR and PY

for THIp=50 and varying levels of THIf



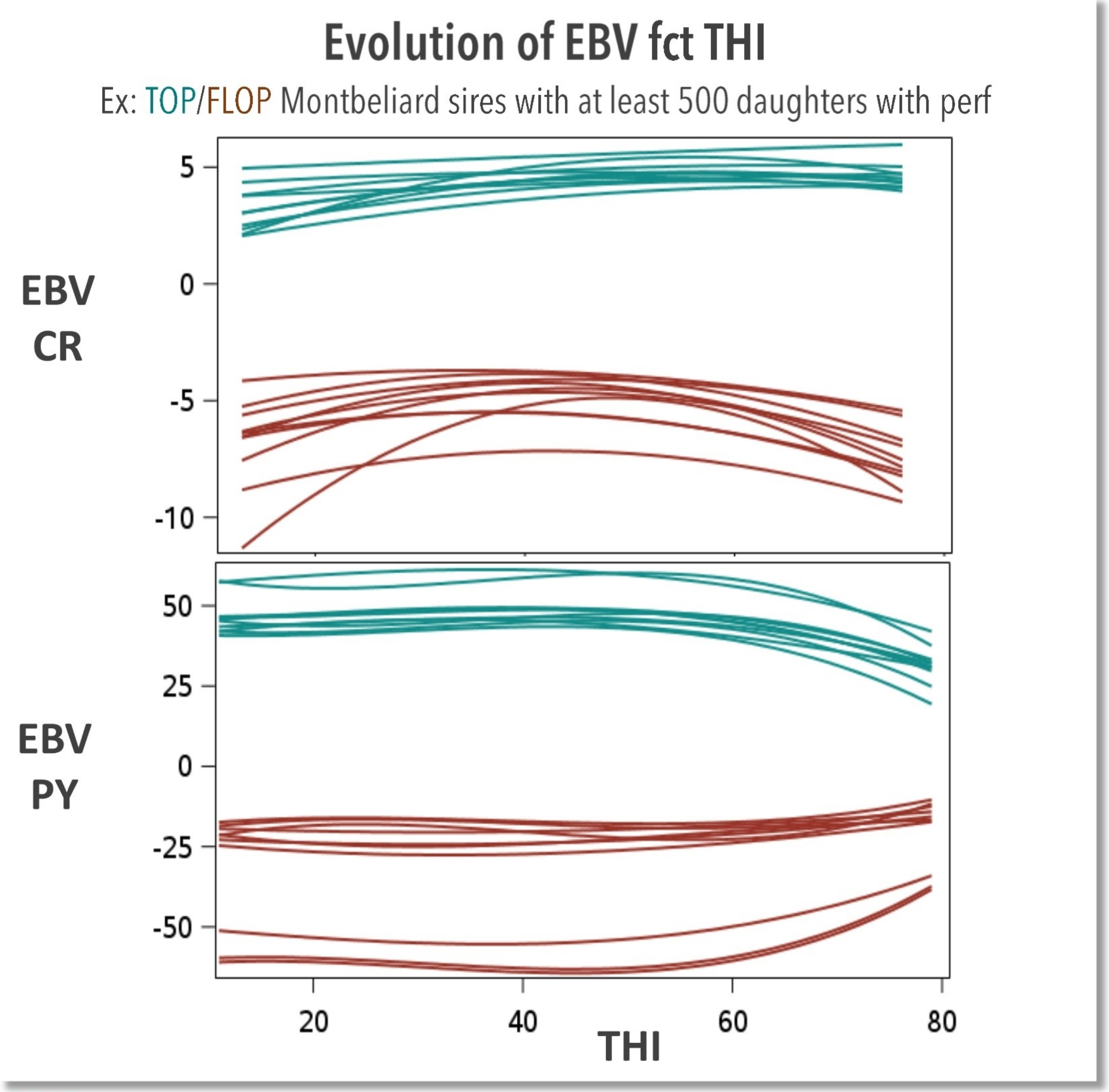
Negative but limited impact of the **current selection on PY** (THIp=50) **on the future CR** (THIf=70)

rg = -0.19 for HOL; -0.20 for MON

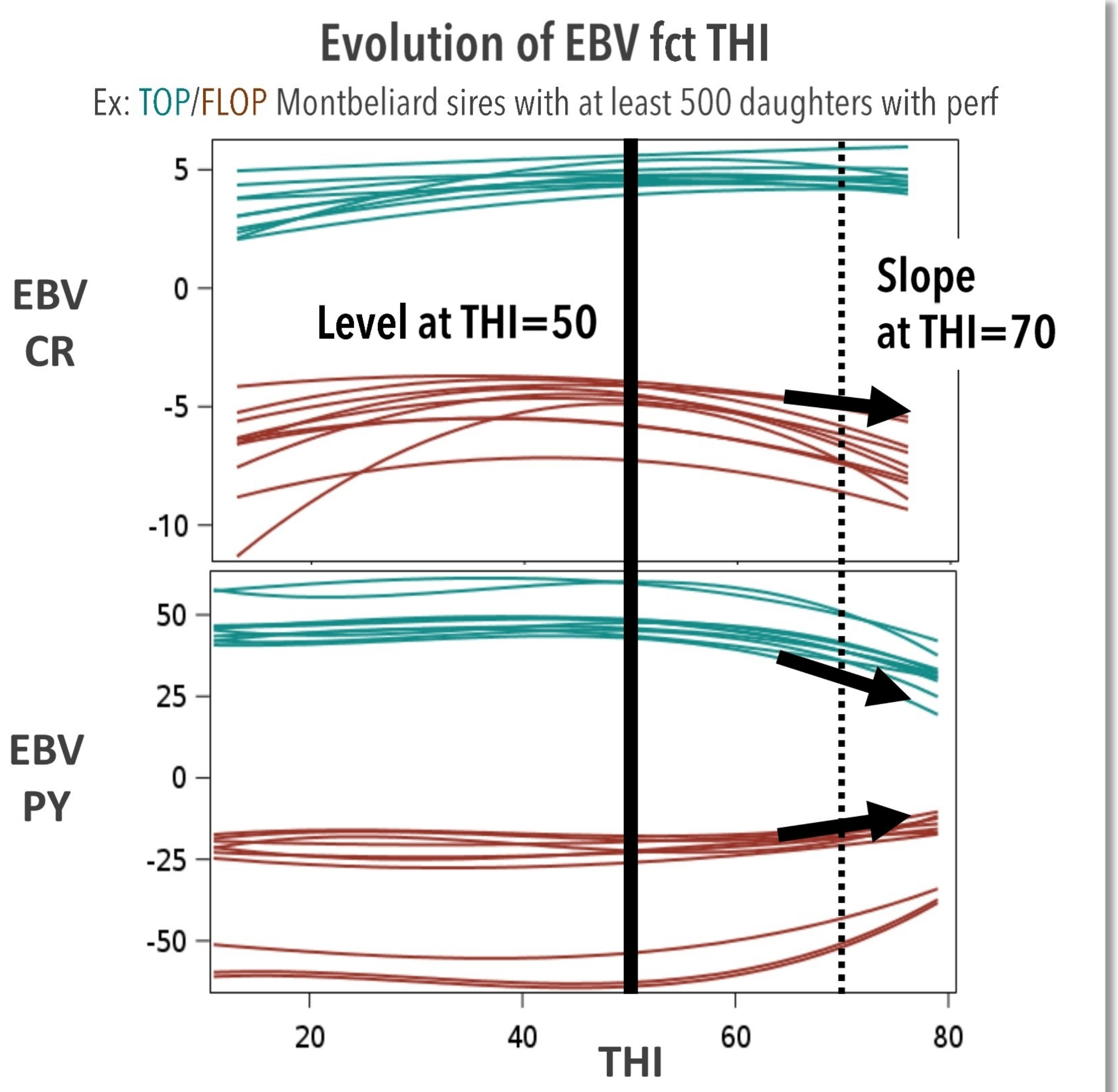
3

Define ways to select
heat tolerant animals

Results – Selection on heat tolerance?

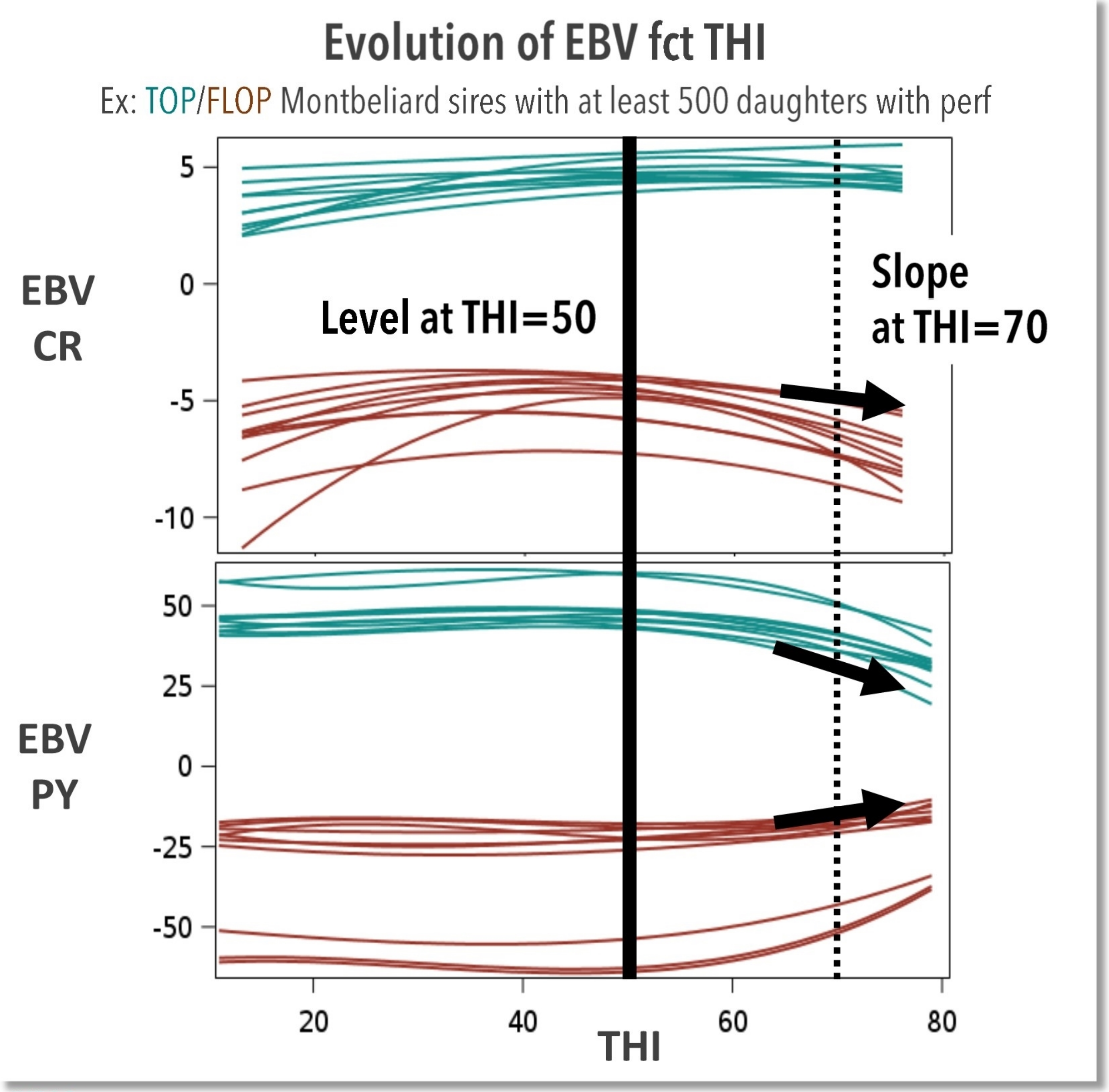


Results – Selection on heat tolerance?



The *slope* gives the evolution of the ranking, toward ↗ or ↘

Results – Selection on heat tolerance?



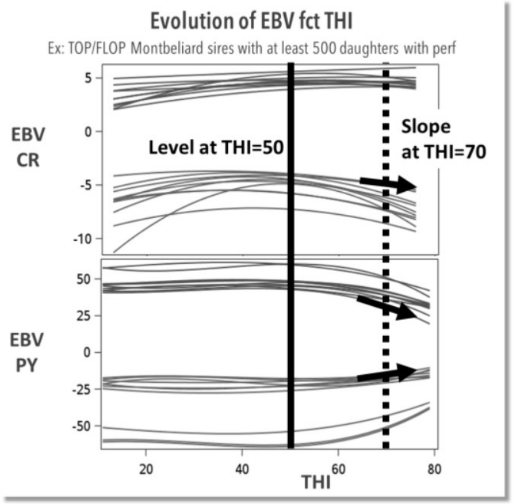
Estimated Breeding Values (EBV) give the *ranking* between animals *at a given THI* not the forecasted performance

All sire families experience a decrease in fertility and production as THI increases

Generally, within-trait the **best sires are always the same** (few GxTHI, results supported by all our univariate analyses, for both breeds)

Context Objective Data Model **Results** Summary

Results – Selection on heat tolerance?

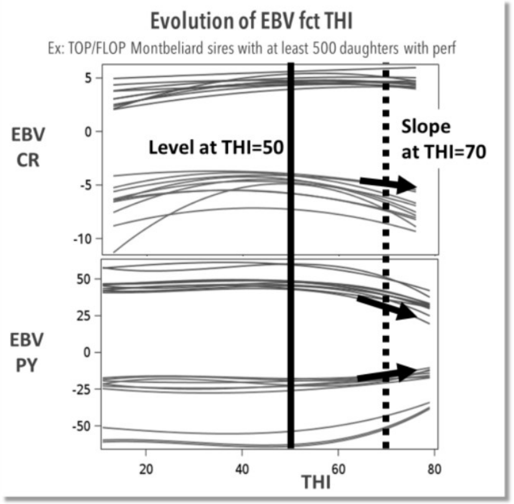


The genetic correlation between "Level at THI=50" and "Slope at THI=70"

⇨ Relationship between the **current breeding values and the trend of BV in warmer conditions**

	CR	PY
Holstein	-0.03	**-0.37**
Montbeliarde	**+0.37**	**-0.71**

Results – Selection on heat tolerance?



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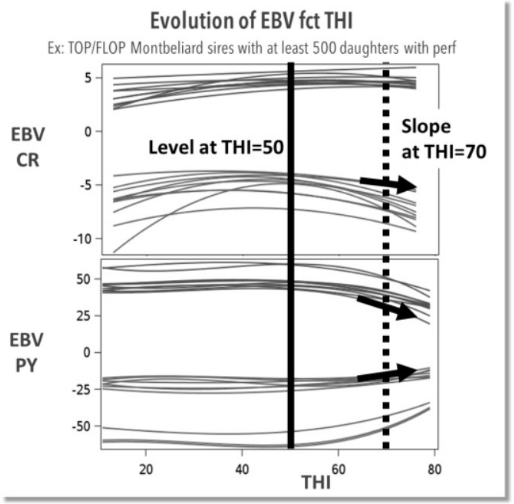
For MON:
Cows already the **poorest reproducers** at THI50 may experience ***even more difficulties*** in heat stress situations

Results – Selection on heat tolerance?



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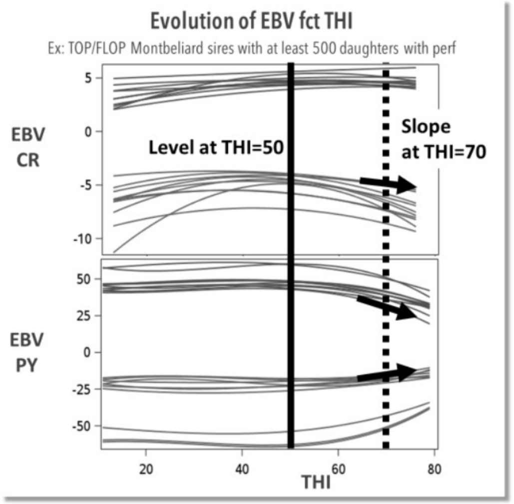
For MON:
Cows already the **poorest reproducers** at THI50 may experience ***even more difficulties*** in heat stress situations

For both breeds:
Higher EBV at THI 50 ⇔ ***least favorable slopes*** at high THI
= animals most affected by heat stress

Results – Selection on heat tolerance?



What about the genetic correlation ***between the slopes?***

Holstein	**+0.41**
Montbeliarde	**+0.28**

Not the same heat tolerance trait

Selection for PY slope:

- *is not antagonistic* with selection for CR slope
- *could be a* ***heat tolerance trait*** (easier to select than CR slope)

Summary

- **In France, the trade-off between production and fertility is moderate**
  When considering mid-lactation production, period when most of first inseminations were performed
- **Trade-off remains more or less stable in heat stress situations**
  Performances recorded at THI>70 are still rare for France
- However, animals with the **best breeding values for production** today will be **the most affected** by temperature increases, **both in term of fertility and production**
- Selection for greater heat tolerance should be done by considering the evolution of production and fertility traits
- The genetic variability of the slopes (heat tolerance traits) are weak ⇨ the potential **genetic gain will be limited**

Acknowledgements

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