Genotype by temperature-humidity index interactions

on milk production and udder health traits in the Montbeliarde cattle breed

Aurélie VINET

Mattalia S, Vallée R, Bertrand C, Bertuzzi P, Cuyabano BCD and Boichard D

World Congress on Genetics Applied to Livestock Production
Rotterdam | The Netherlands
3 - 8 July 2022

Context

- The evolution of the climate will lead to ***higher temperatures*** but also to more frequent ***extreme events***
- For cattle, exposure to high temperatures induces **a decrease in their production, an alteration of their health, their reproductivity or their welfare**
- ***Identification of heat-tolerant*** **animals within the high production breeds** will be useful in long term if these animals are able to maintain high production when they are exposed to hot temperatures

Objective

- ***Impact of heat stress*** on performances of Montbeliarde cows bred in France ⇔ *population level*

- ***Genotype x Environment interactions*** ⇔ *individual level*

  environment = meteorological gradient

Data

Production data

Test-day performances (2016-2020)

- milk yield (MY)
- fat and protein contents/yields (FC, PC, FY, PY)
- somatic cells score (SCS)

First and second lactations were analyzed separately

Meteorological data

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

THI_3d = average THI over a 3−day period (2d before the TD date + the TD date)

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

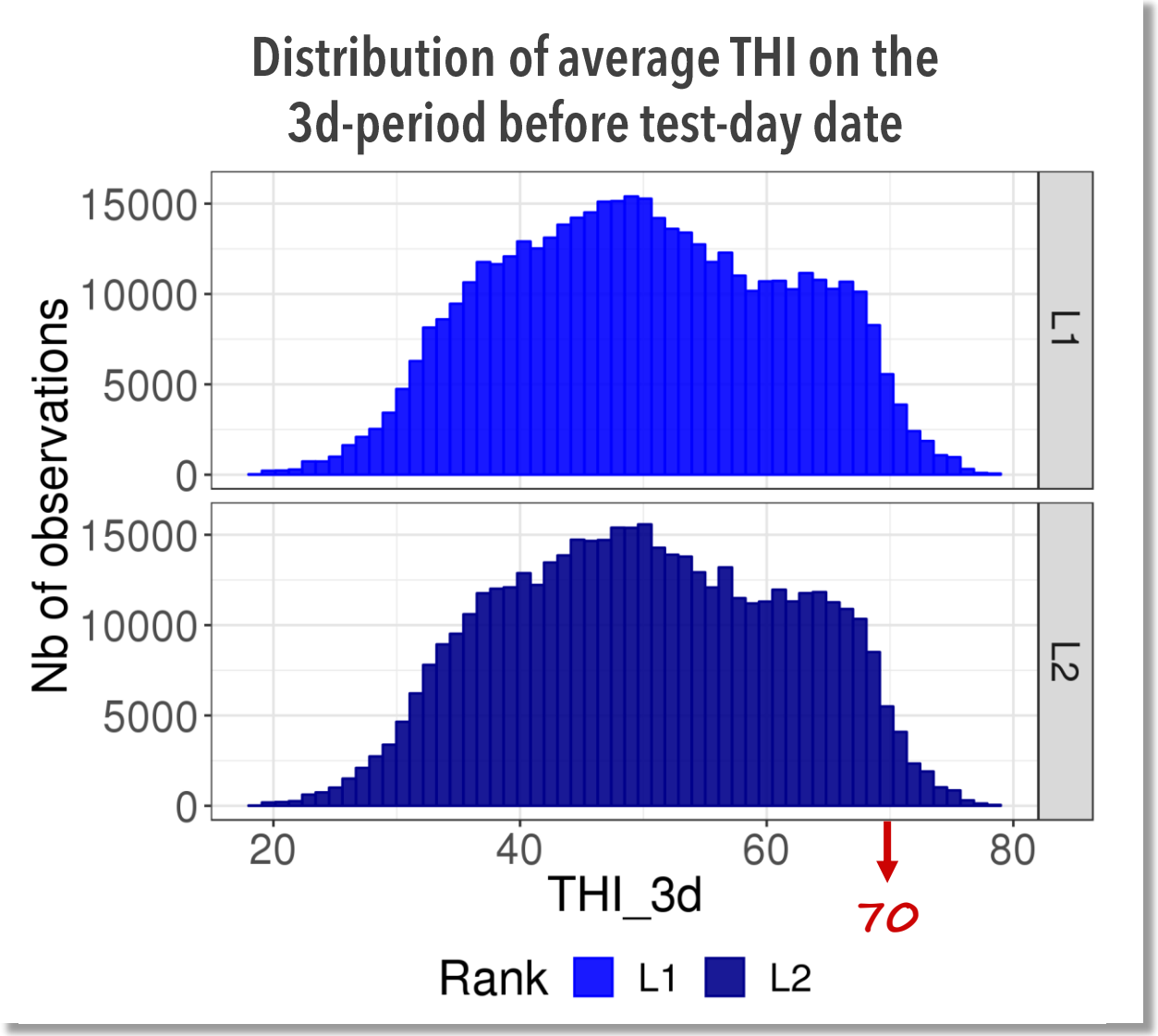
Match with zip code of each farm

Whole dataset

Datasets

	L1	L2
nb records	446,717	457,516
nb cows with data	55,650	58,229
% perf recorded at THI ≥ 70	3.2%	3.1%

THI = 70 ⇔ 22-24°C



Impact of the THI on performances

Population level: Model

$$y_{hjklmnip} = \mathrm{HY_h} + \mathrm{DIM_j} + \mathrm{AGE_CALV_k} + \mathrm{GEST_l} + \mathrm{SEAS_CALV_m} + \mathbf{THI_n} + g_i + pe_p + e_{hjklmnip}$$

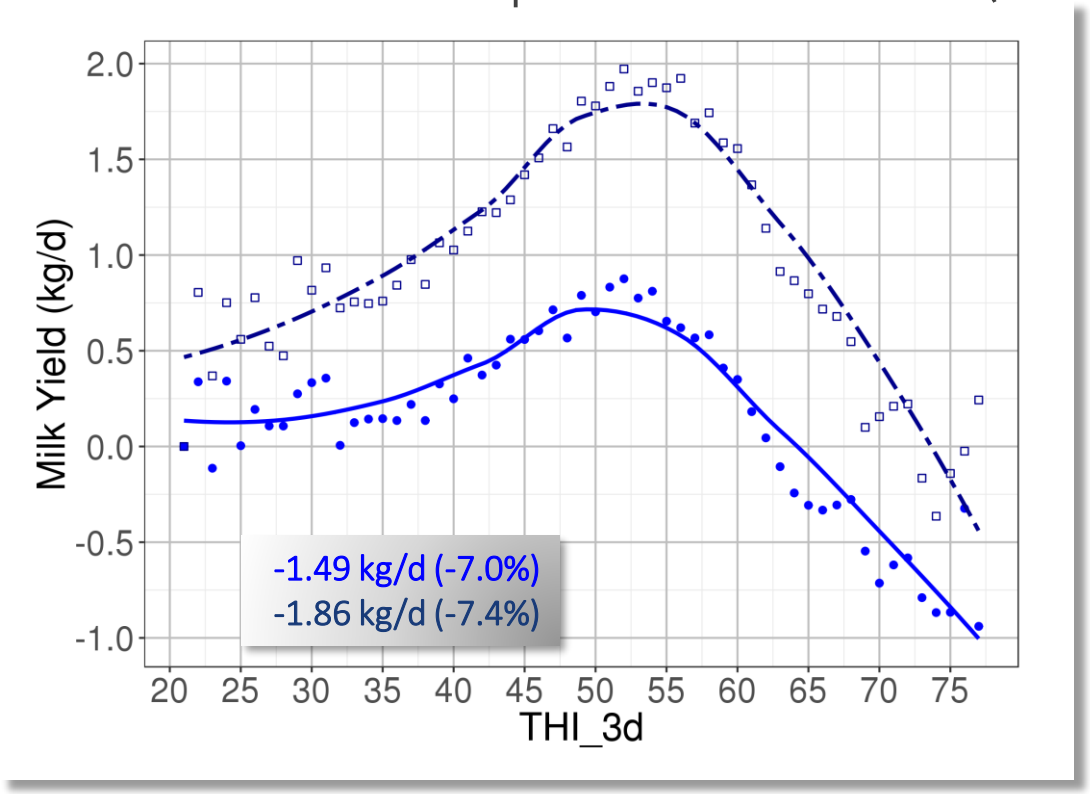
The **THI** is considered as a **fixed effect**

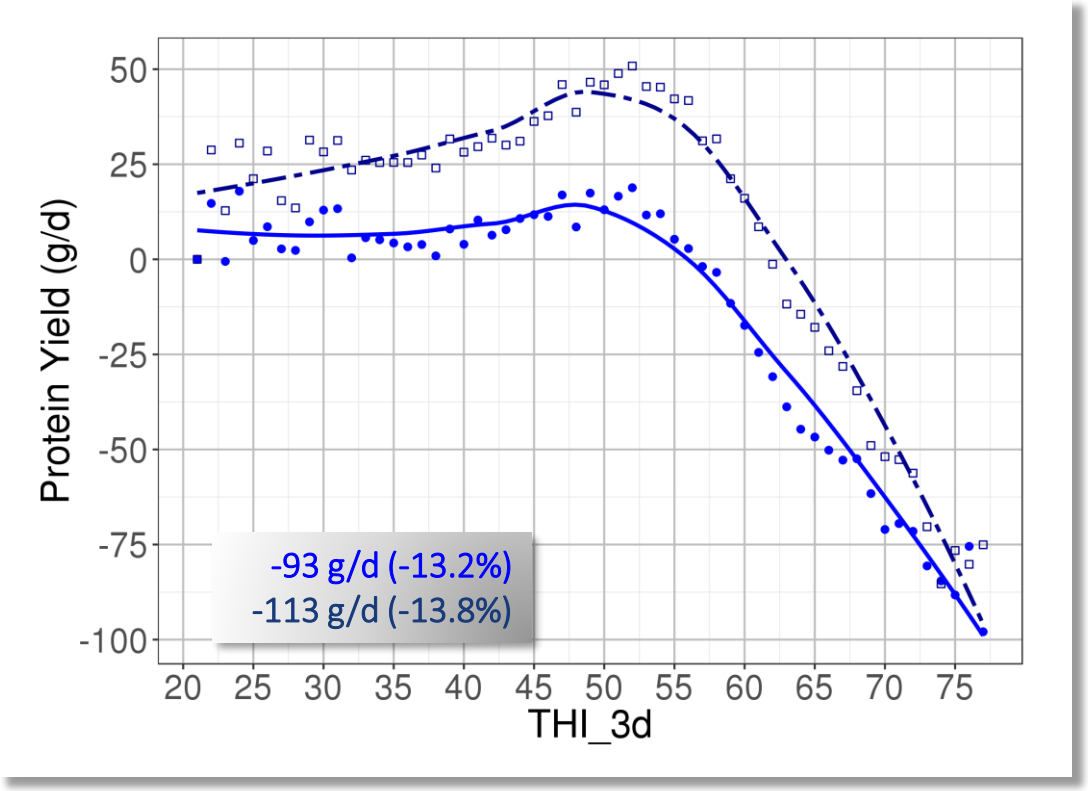
⇔ Average effect of the THI on the performances of all females

Software: WOMBAT (Meyer K., 2007)

Population level: Results

Least-squares solutions in first (solid line) and second lactation (dashed line)



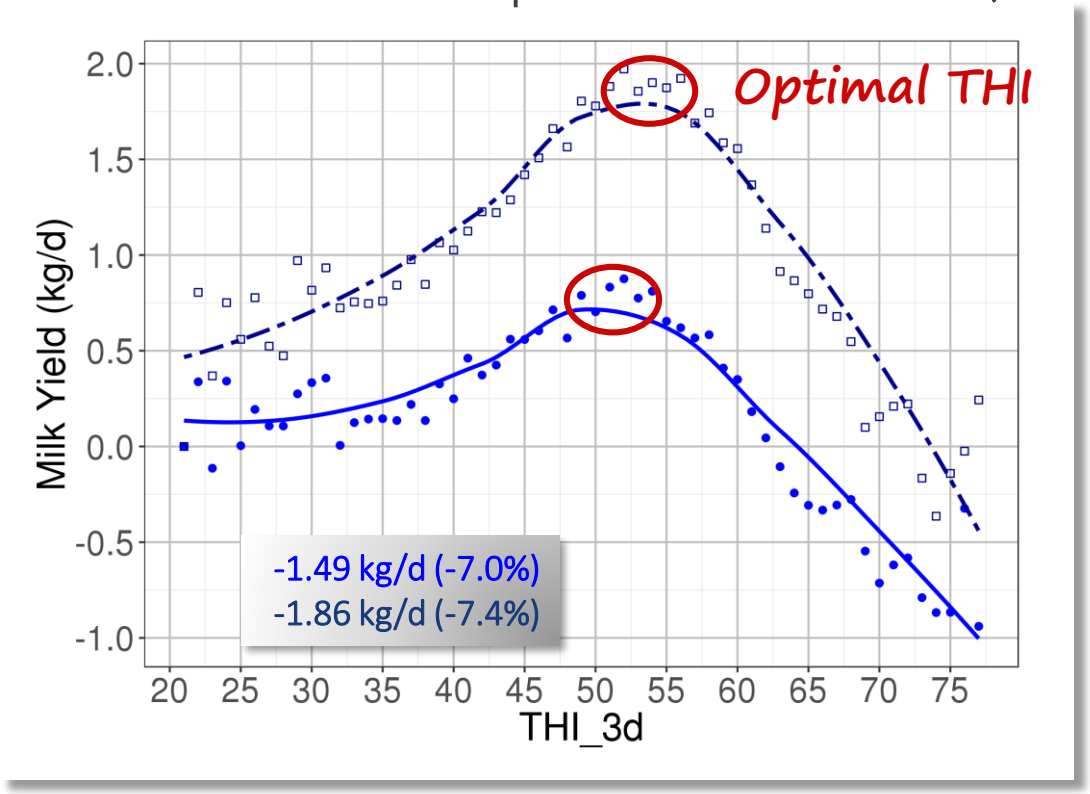


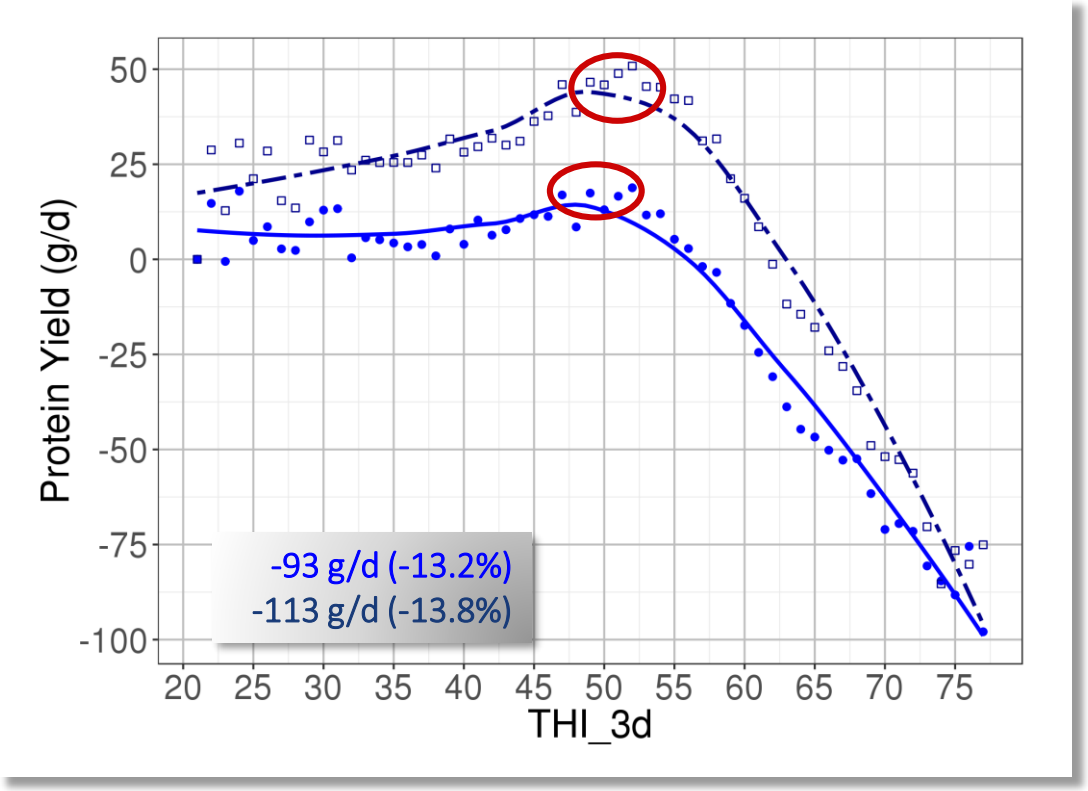
Considering all traits:

- ***Optimal THI*** varies between traits, but is ***always ≤ THI 55*** (⇔ 12 to 13°C)
- Within-trait, same optimum in first and second lactation
- 5 to 14% decline in performances between optimal THI and THI>70

Population level: Results

Least-squares solutions in first (solid line) and second lactation (dashed line)





Considering all traits:

- **Optimal THI** varies between traits, but is **always ≤ THI 55** (⇔ 12 to 13°C)
- Within-trait, same optimum in first and second lactation
- 5 to 14% decline in performances between optimal THI and THI>70

Genotype x Environment (THI) interactions

GxE: Random Regression Model

The environment is described by a continuous variable ⇨ the ***response of each genotype*** is modeled as a ***continuous curve*** along the environmental gradient

$$y_{hjkli_td} = \mathrm{HTD_h} + \mathrm{DIM_j} + \mathrm{AGE_CALV_k} + \mathrm{GEST_l} + \sum_{r=0}^{5} Z_r(\boldsymbol{t})(\boldsymbol{d})\boldsymbol{g_{ir}} + \sum_{m=0}^{5} W_m(\boldsymbol{t})(\boldsymbol{d})\boldsymbol{pe_{im}} + e_{hjkli_td}$$

Functions of regression dependent on *THI* or dependent on *DIM*

⇨ For each function: one coefficient of regression is estimated for each animal

⇨ Trajectories of variances and EBV along the THI & DIM gradients

Software: WOMBAT (Meyer K., 2007)

GxE: Random Regression Model

The environment is described by a continuous variable ⇨ the ***response of each genotype*** is modeled as a ***continuous curve*** along the environmental gradient

$$y_{hjkli_td} = \mathrm{HTD_h} + \mathrm{DIM_j} + \mathrm{AGE_CALV_k} + \mathrm{GEST_l} + \sum_{r=0}^{5} Z_r(\boldsymbol{t})(\boldsymbol{d})\boldsymbol{g_{ir}} + \sum_{m=0}^{5} W_m(\boldsymbol{t})(\boldsymbol{d})\boldsymbol{pe_{im}} + e_{hjkli_td}$$

Functions of regression dependent on *THI* or dependent on *DIM*

⇨ For each function: one coefficient of regression is estimated for each animal

⇨ Trajectories of variances and EBV along the THI & DIM gradients

Legendre polynomials:

Function of order *0* (cst, **inpdt of THI and DIM**)

Functions of order *1*, *2* and *3* dpdt **THI**

Functions of order *1* and *2* dpdt **DIM**

Software: WOMBAT (Meyer K., 2007)

GxE: Random Regression Model

The environment is described by a continuous variable ⇨ the ***response of each genotype*** is modeled as a ***continuous curve*** along the environmental gradient

$$y_{hjkli_td} = \mathrm{HTD_h} + \mathrm{DIM_j} + \mathrm{AGE_CALV_k} + \mathrm{GEST_l} + \sum_{r=0}^{5} Z_r(t)(d)\,g_{ir} + \sum_{m=0}^{5} W_m(t)(d)\,pe_{im} + e_{hjkli_td}$$

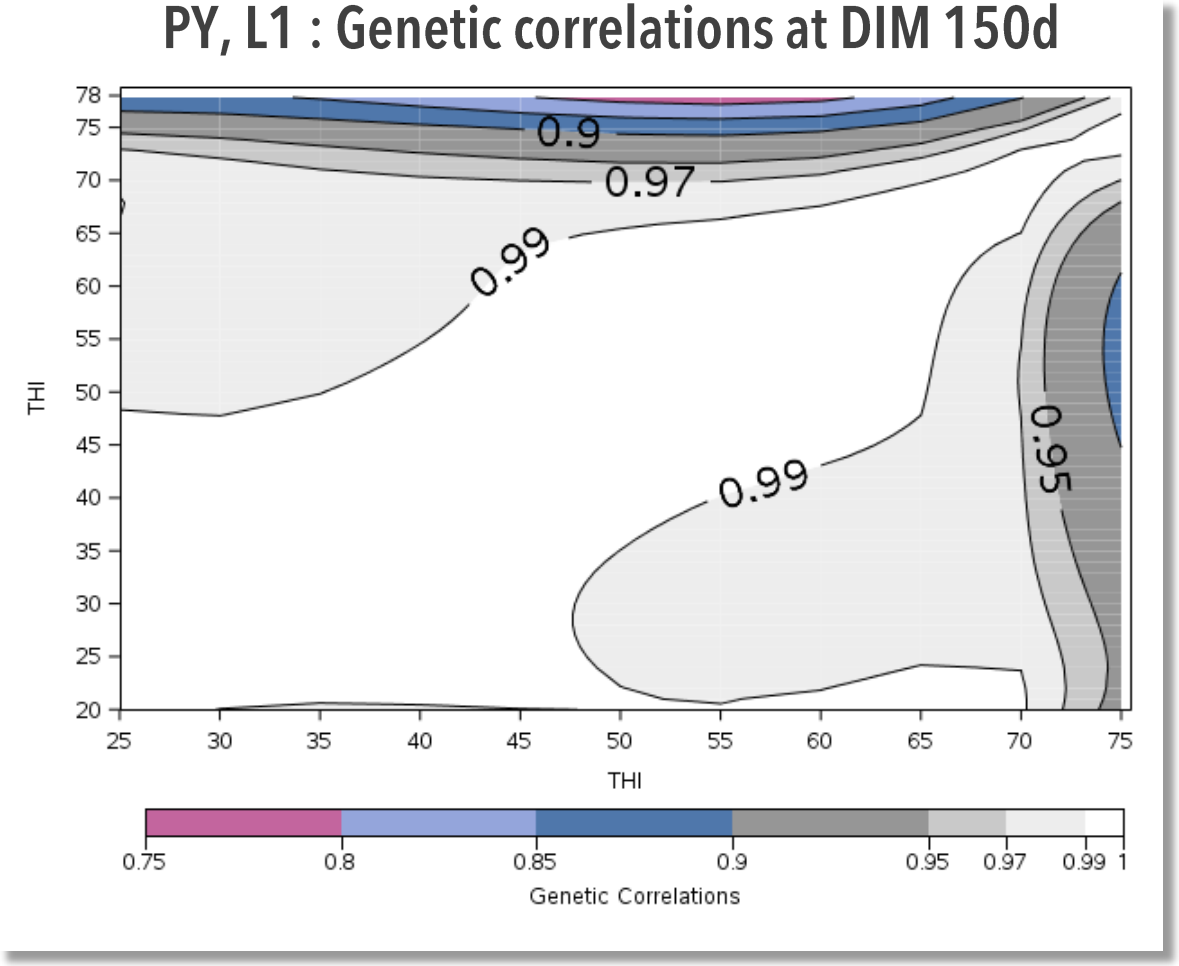
Functions of regression dependent on *THI* or dependent on *DIM*

Permanent effect is also ***regressed*** by functions of ***THI/DIM***

Residual variances were considered ***heterogeneous*** across DIM and across THI classes

Software: WOMBAT (Meyer K., 2007)

GxE: Genetic Correlations

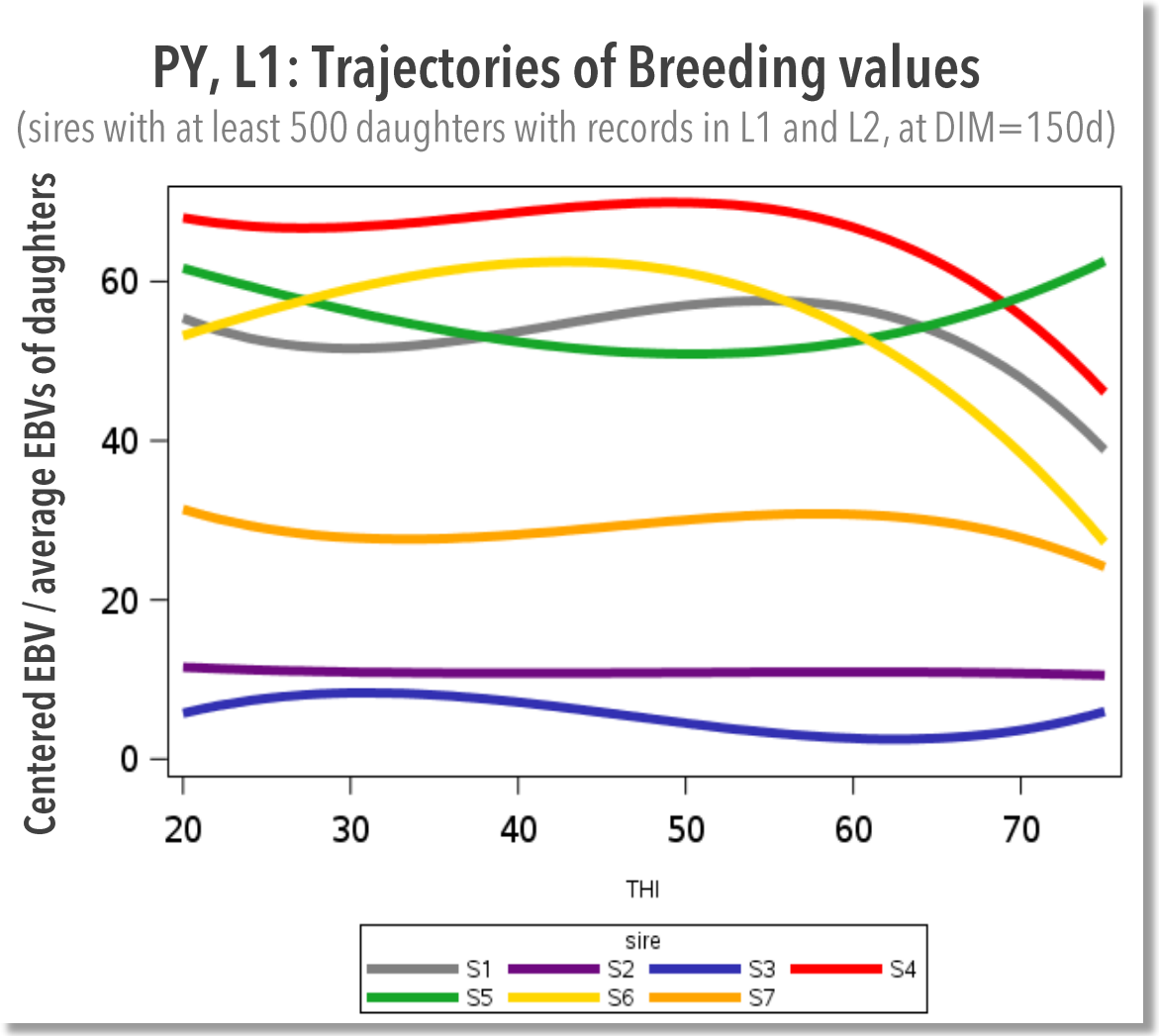


All traits:

No correlations below 0.80
most of them above 0.90

⇔ *no GxE* **identified in our data**

GxE: Breeding Values



Generally, within-trait the **best sires are always the same**

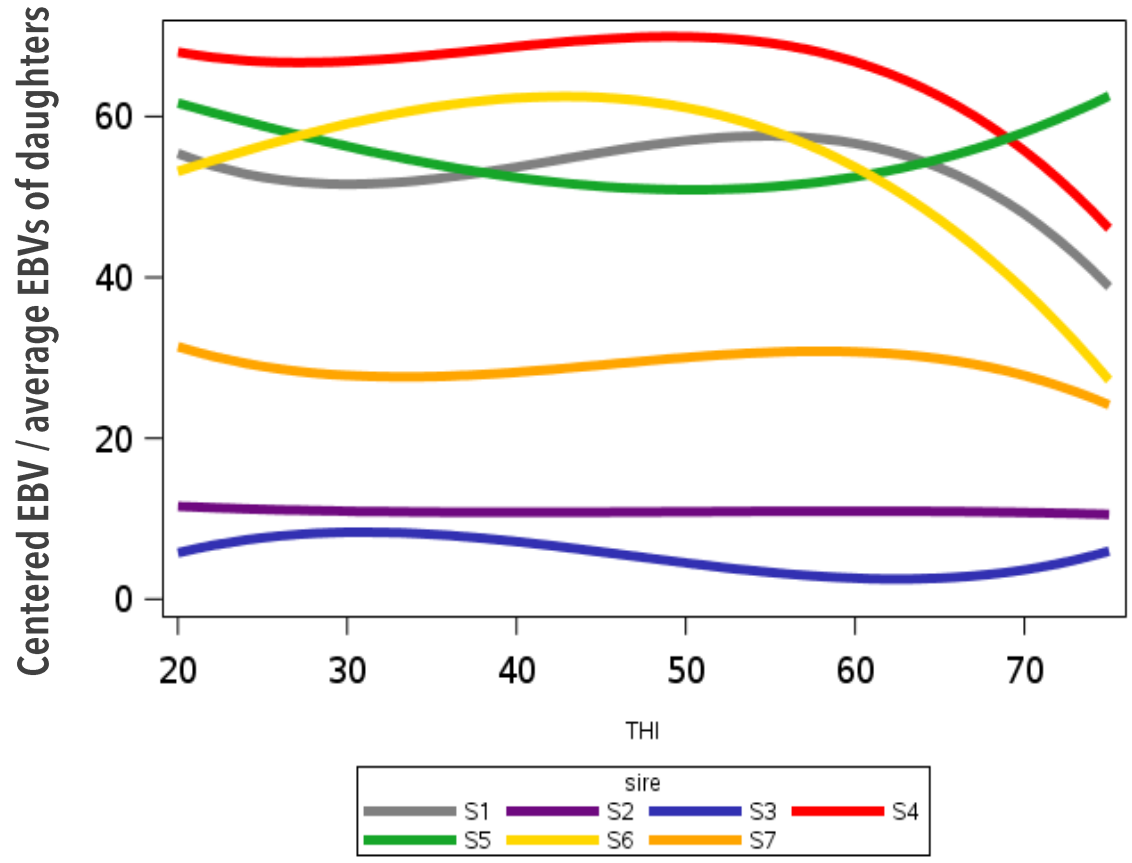
There are some ***re-rankings*** and a variability of ***slope*** over THI values

Some sires are **more tolerant** to heat stress

GxE: Breeding Values

PY, L1: Trajectories of Breeding values

(sires with at least 500 daughters with records in L1 and L2, at DIM=150d)



Generally, within-trait the **best sires are always the same**

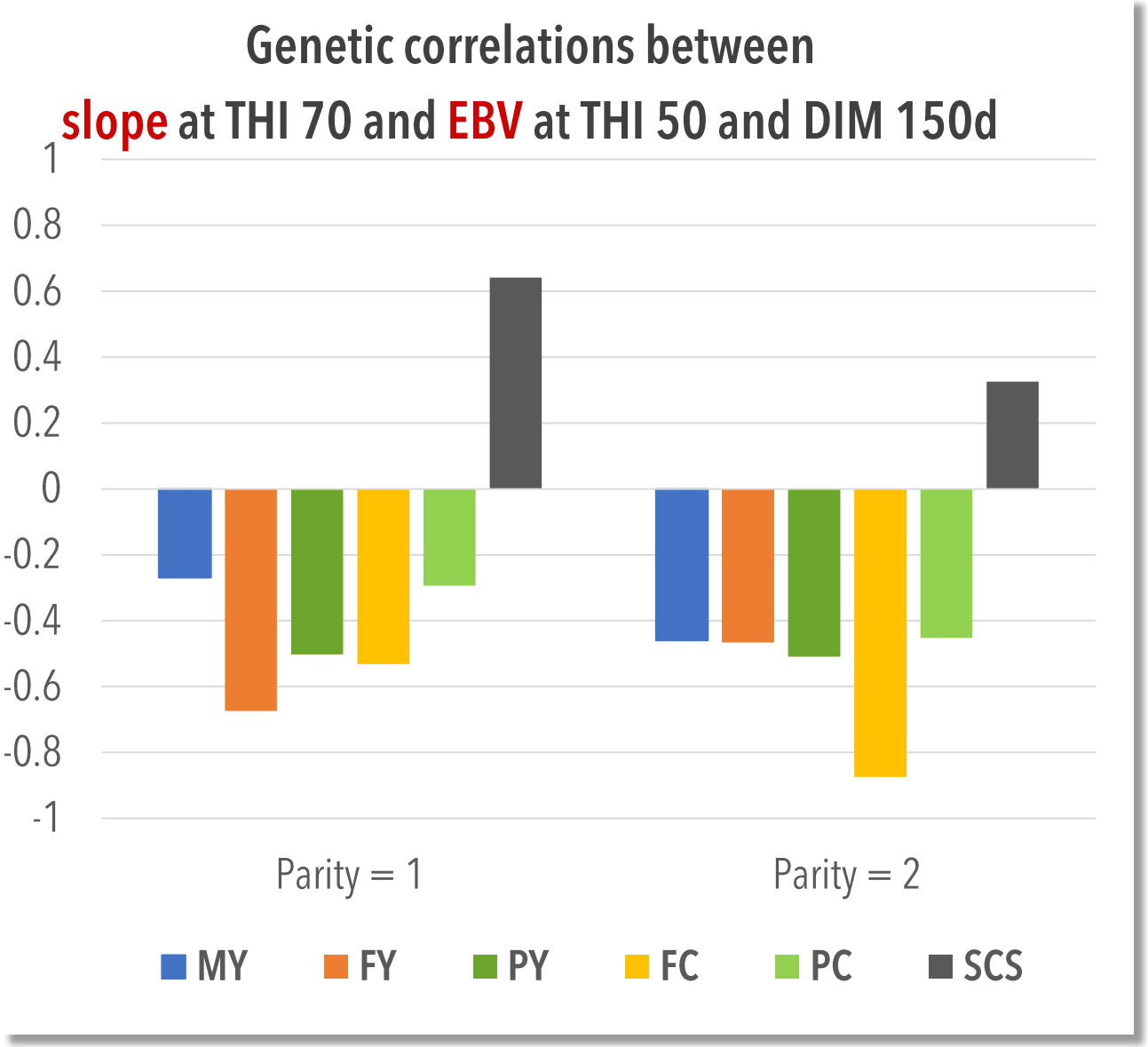
There are some ***re-rankings*** and a variability of ***slope*** over THI values

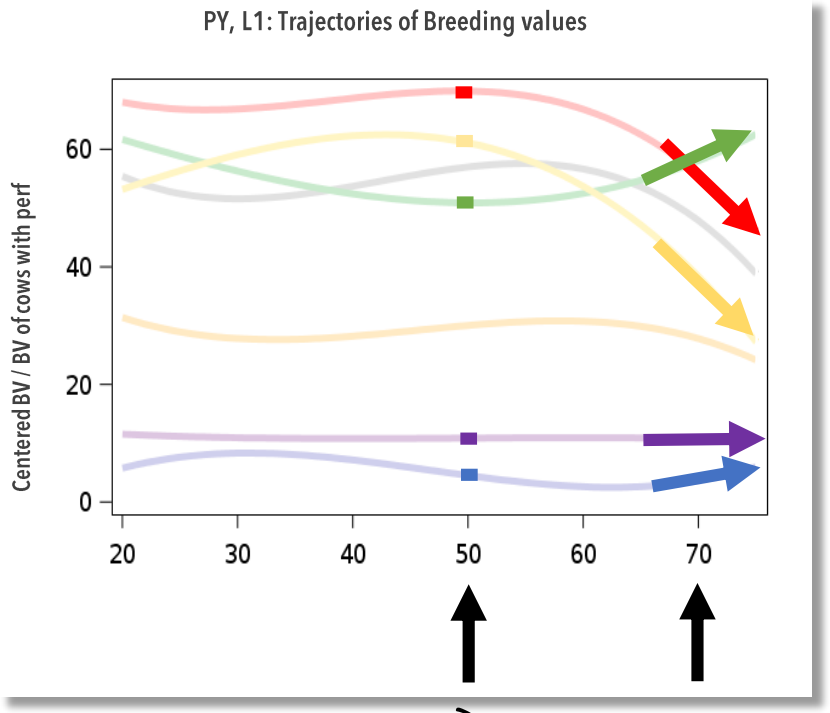
Some sires are **more tolerant** to heat stress

*EBV give the **ranking** between animals **at a given THI** not the forecasted production*

All sire families experience a decrease in production as THI increases

GxE: Slopes at high THI

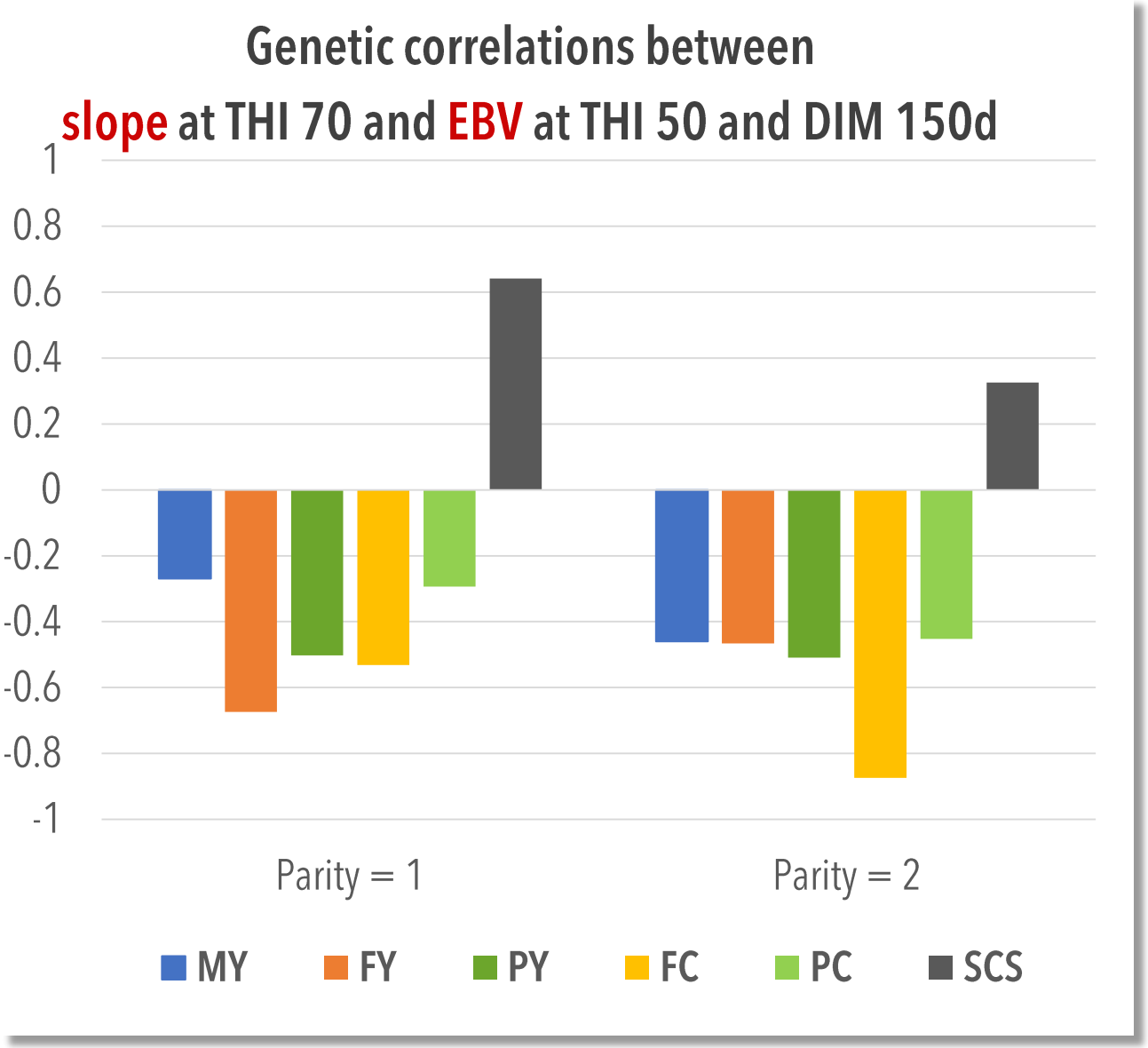




EBV (THI 50, DIM 150)

Slope at THI 70

GxE: Slopes at high THI



Genetic correlations unfavorable:

< 0 for all production traits

> 0 for SCS

All traits:

higher EBV ⇔ **least favorable slopes** at high THI

least favorable slopes

= *slopes for prod traits*

= *slopes for SCS*

Summary

Population level

- The **optimal temperature** of Montbeliarde cows raised in France currently is **≤ 13°C** for production traits and SCS
- The **rise in temperatures** will lead to a **decrease in all performances**

Individual level

- **Few G x THI** interactions but trajectories of EBV that allow to identify **animals more tolerant to heat stress**

Acknowledgements

Rumigen
TOWARDS IMPROVEMENT OF RUMINANT BREEDING THROUGH GENOMIC AND EPIGENOMIC APPROACHES

CAICalor

HORIZON 2020
LE PROGRAMME DE RECHERCHE ET D'INNOVATION DE L'UNION EUROPÉENNE

APIS-GENE
Investir Innover Valoriser