Rumigen

TOWARDS IMPROVEMENT OF **RUMI**NANT BREEDING
THROUGH **GEN**OMIC AND EPIGENOMIC APPROACHES

Impact of heat stress on production, udder health and reproduction in dairy cows in the Netherlands, Spain and France

C. Diaz, M. Ramon, M.J. Carabaño

M. Calus, J. Vandenplas, H.A. Mulder

A. Vinet, B.C.D. Cuyabano, D. Boichard

S. Aguerre, J. Promp, R. Vallée, S. Mattalia

INIA Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

Castilla-La Mancha Consejería de Agricultura, Agua y Desarrollo Rural

IRIAF Instituto Regional de Investigación y Desarrollo Agroalimentario y Forestal de Castilla-La Mancha

WAGENINGEN UNIVERSITY & RESEARCH

INRAE la science pour la vie, l'humain, la terre

INSTITUT DE L'ELEVAGE idele

EcoGen Webinar – Resilience and Adaptation
24/04/2025

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000226

RUMIGEN – Objectives of the project and focus on WP3

- **Climate change**
  - **Global rise of temperature**
  - **Extreme events** such as **heat waves :** more frequent, longer and more intense
- **Dairy cattle** are particularly **sensitive to heat stress**
  Impacts on their physiology, health, welfare and zootechnical performances

➢ **RUMIGEN (2021 – 2026) : Provide breeding tools to achieve a better adaptation of cattle to climate change**

- **WP3 - Measure the impact of heat stress on the performances of**
  - **dairy cows:**
    - Evaluate the **impact of heat stress on performances** and the **genetic variability** for heat tolerance
    - Evaluate the **impact of heat stress on trade-offs** between production and reproduction
  - **their daughters:**
    - Evaluate the **impact of *in utero* heat stress** on **offspring phenotypes**

RUMIGEN WP3 – Description of the datasets

- **Breeds: Holstein (FRA, NLD, SPA), Montbéliarde (FRA), MRY (NLD)**

- **Existing large scale national data:**
  - **Zootechnical performances in 1st and 2nd lactation** :
    - Production : Test-day records on Milk Yield (MY), Fat Yield (FY), Protein Yield (PY)
    - Udder health : Somatic cell score (SCS)
    - Reproduction : Conception Rate at 1st artificial insemination

	FRA	NLD	SPA
Period	2016-2020	2010-2020	2010-2021
# cows	7 Mo (HOL) 1.2 Mo (MON)	500,000 (HOL) 10,000 (MRY)	1 Mo (HOL)

  - **Pedigrees**
  - **Daily weather information provided by national meteo agencies associated to each herd, using their ZIP code or farm coordinates**

    Temperature Humidity Index : **THI** = (1.8*T+32)-(0.55-0.0055*RH)*(1.8*T-26)
    with T: average daily temperature (°C) and RH: average daily humidity
    (source: National Research Council, 1971)

Impact of heat stress on dairy cows performances

-

Population level

Crédit photo : https://www.m-elevage.fr/

Crédit photo : https://www.paysdemontbeliard-tourisme.com/la-vache-montbeliarde

RUMIGEN WP3 – Estimation of the effect of a variation of THI at the population level

Methods

- Each lactation was analysed separately
- For the cow i, on test-day j, submitted to a given THI:
  - **Production and SCS :** y_{ij} = **THI** + ∑ other fixed effects$_{i,j}$ + a_i + p_i + e_{ij}
  - **Reproduction :** y_i = **THI** + ∑ other fixed effects$_i$ + a_i + e_i

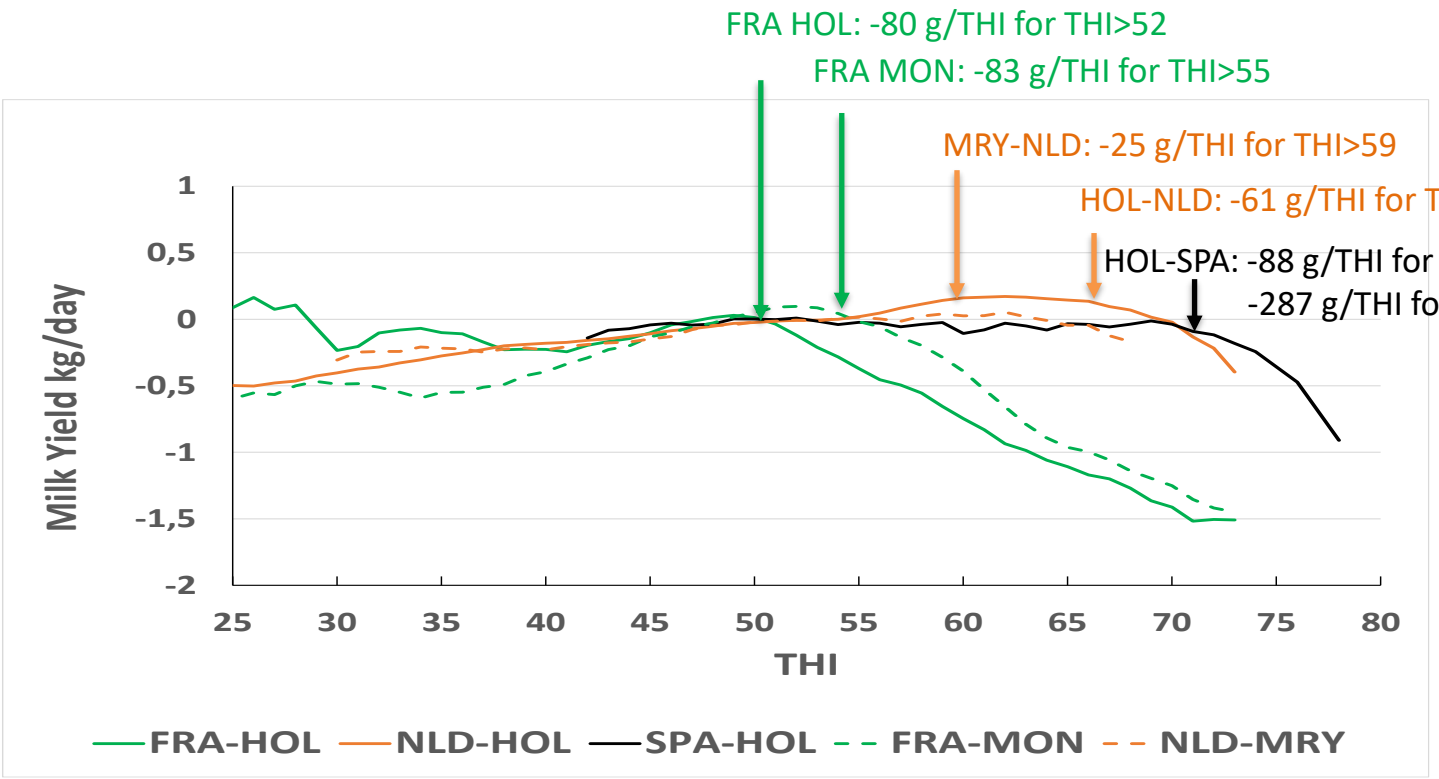
With

- y_{ij}: performance of the cow
- Random effects:
  - a_i :additive genetic value
  - p_i : permanent environment effect
  - e_{ij}: residual
- **Heat stress effect** : **THI** as a **fixed effect**
  - **Production, SCS**: averaged within 3 days before test-day (from day -2 to day 0)
  - **Reproduction**: averaged within 8 days after artificial insemination (day 0 to day 7)

RUMIGEN WP3 – Negative impact of increasing THI on milk yield in cows in 1rst lactation – Population level

THI ≈ Average T°

THI 50 ≈ 9°C
THI 55 ≈ 12°C
THI 65 ≈ 19°C
THI 75 ≈ 25°C

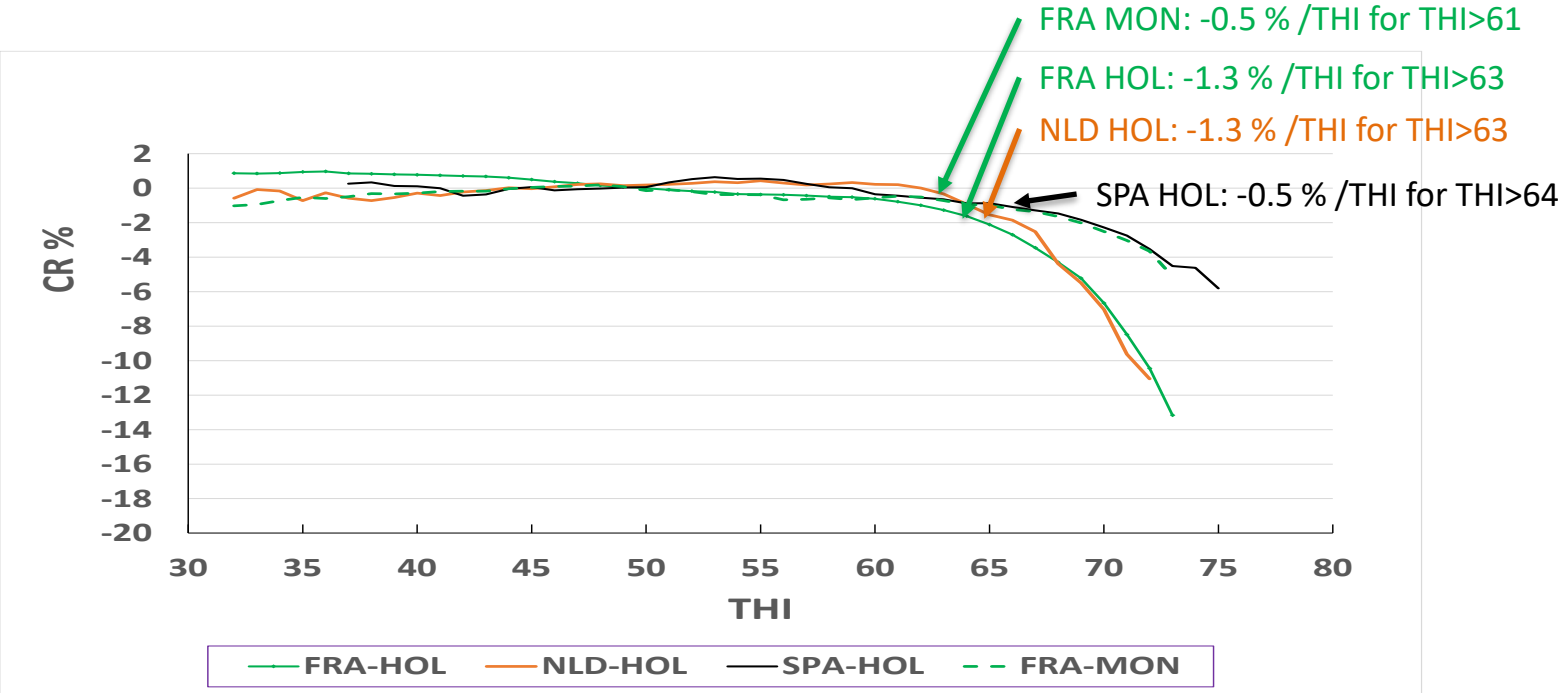


- **Similar rate of decline with daily production loss of 6 to 11% between THI 50 and THI 70**
- **Different thresholds** identified with **more differences among countries than among breeds** probably in relation with the different **farming conditions**
  - Exposure to outdoor weather conditions
  - Possible confusion between THI effect and transition periods from indoor to pasture rations
  - Mitigation and acclimatation

RUMIGEN WP3 – Negative impact of increasing THI on conception rate in cows in 1rst lactation – Population level

THI ≈ Average T°

THI 50 ≈ 9°C
THI 55 ≈ 12°C
THI 65 ≈ 19°C
THI 75 ≈ 25°C



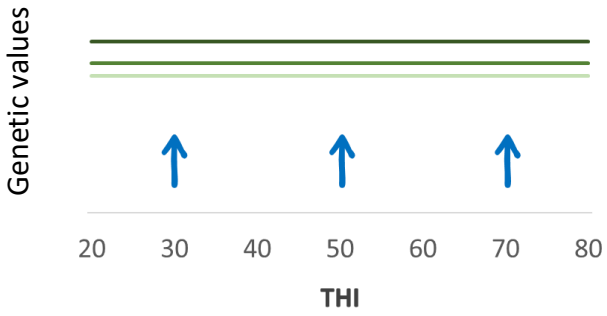
- **Thresholds** were more **homogeneous**
- **Steeper decline for French and Dutch Holstein cows** than French Montbéliarde and Spanish Holstein cows
  - Acclimatation and housing conditions of Spanish Holstein cows ?
  - Different genetic abilities for French Montbéliarde cows ?

Genotype x Environment interactions
-
Individual level

RUMIGEN WP3 – Estimation of the effect of a variation of THI at the individual level

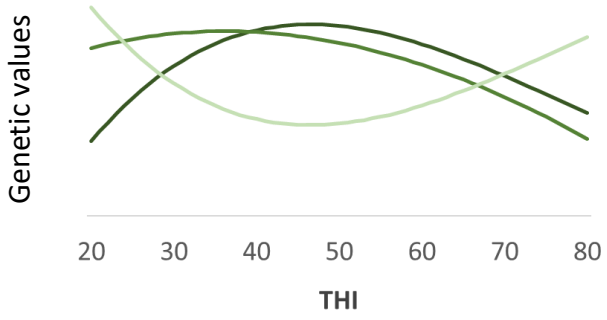
- **Objective: Trajectories of variances and genetic values along the THI gradient to study GxTHI interactions**
- **Methods : Random regression model** - what is the interest of this type of model ?

Classical model



- A **unique genetic value** for each individual
- **Constant** whatever the environment

Random regression model



Source : Aurélie Vinet

- The environment is described by a continuous gradient
- The **genetic value** of an individual **varies along the environment gradient**

RUMIGEN WP3 – Estimation of the effect of a variation of THI at the individual level

- **Objective: Trajectories of variances and genetic values along the THI gradient to study GxTHI interactions**

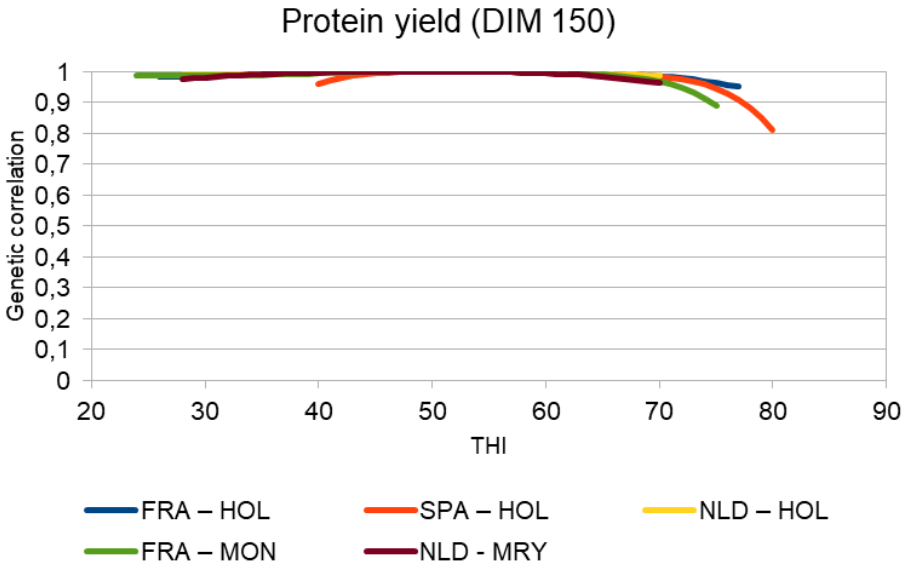
- **Methods : Random regression model**

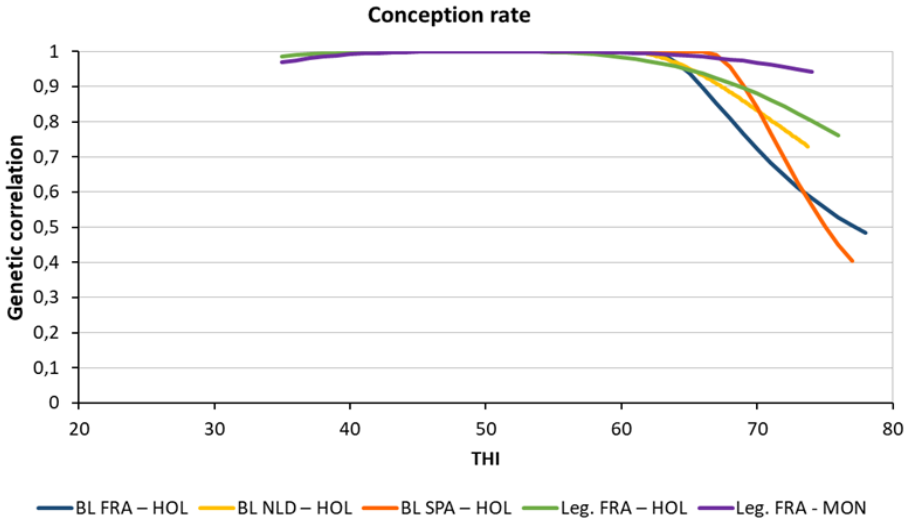
$$\boldsymbol{y} = \sum \text{fixed effects} + f(\mathbf{GxTHI}) \; (+f(\mathbf{pxTHI})) + \mathbf{e}$$

- $\boldsymbol{y}$: performances
- $f(\mathbf{GxTHI})$: random additive genetic effects
  - **Production, SCS :** Legendre polynomials
  - **Reproduction :** Broken stick model / Legendre polynomials
- $f(\mathbf{pxTHI})$: random permanent environment effect
- $\mathbf{e}$: residual

- **Heat stress effect** :
  - **Production, SCS**: averaged within 3 days before test-day (from day -2 to day 0)
  - **Reproduction**: averaged within 8 days after artificial insemination (from day 0 to day 7)

RUMIGEN T3.1 – Evolution of genetic correlations for protein yield and conception rate between THI50 and other THI values





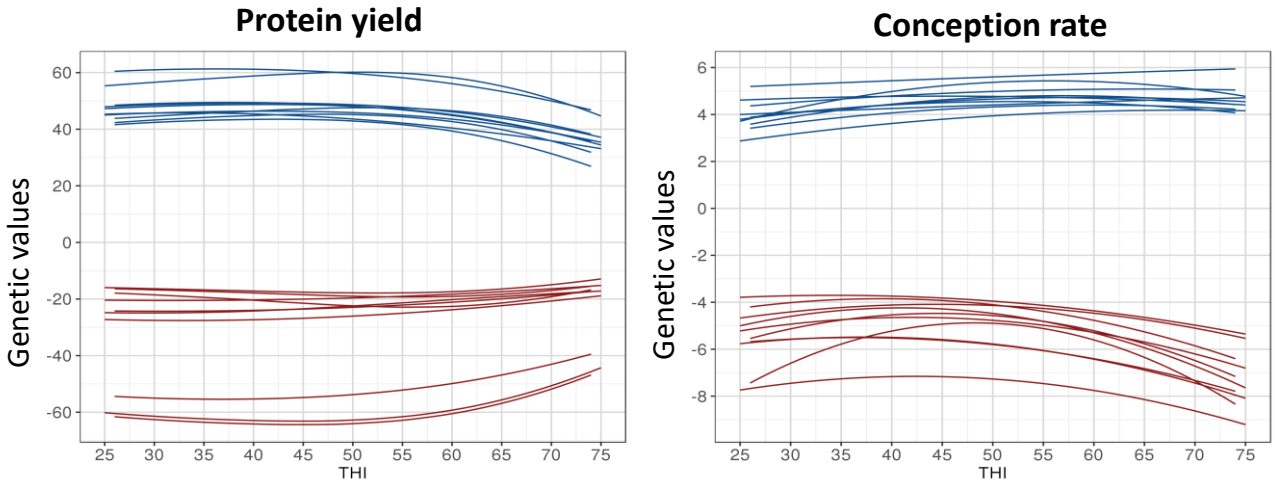
- **Production traits and SCS**
  - High genetic correlations (≥ 0.8): **little to no GxE interactions**
- **Conception rate**
  - Moderate genetic correlations after breakpoint in Holstein populations: **GxE interactions observed**

RUMIGEN WP3 – Impact of increasing THI on elite reproducers

- **Within–trait: few re-rankings** but the **differences between sires** can be **reduced or amplified**

Evolution of genetic values along THI gradient

TOP 10 & FLOP 10 of Montbéliard sires at THI50



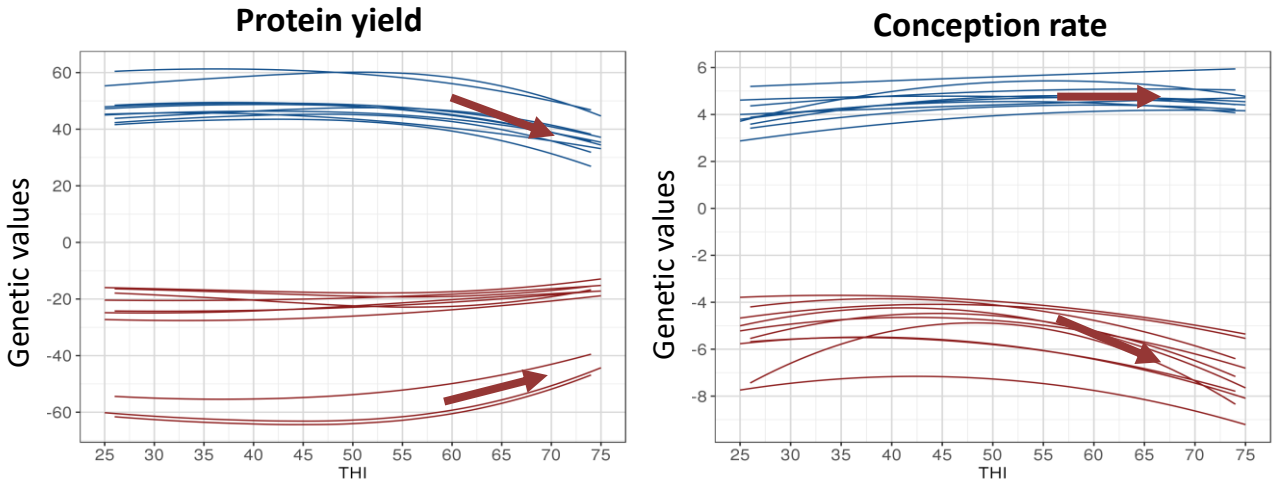
- **Production traits:** decreased genetic variability with increasing THI
  Cows with the highest level of production will be the most impacted.
- **Conception rate:** increased genetic variability with increasing THI
  Cows that have the most difficulties to reproduce will have even more difficulties.

RUMIGEN WP3 – Impact of increasing THI on elite reproducers

- **Within–trait: few re-rankings** but the **differences between sires** can be **reduced or amplified**

Evolution of genetic values along THI gradient

TOP 10 & FLOP 10 of Montbéliard sires at THI50



- **Slopes of decline** in performances **vary from an individual to another**

➢ **Some animals are more tolerant to heat stress than others**

RUMIGEN WP3 – Impact of increasing THI on trade-offs

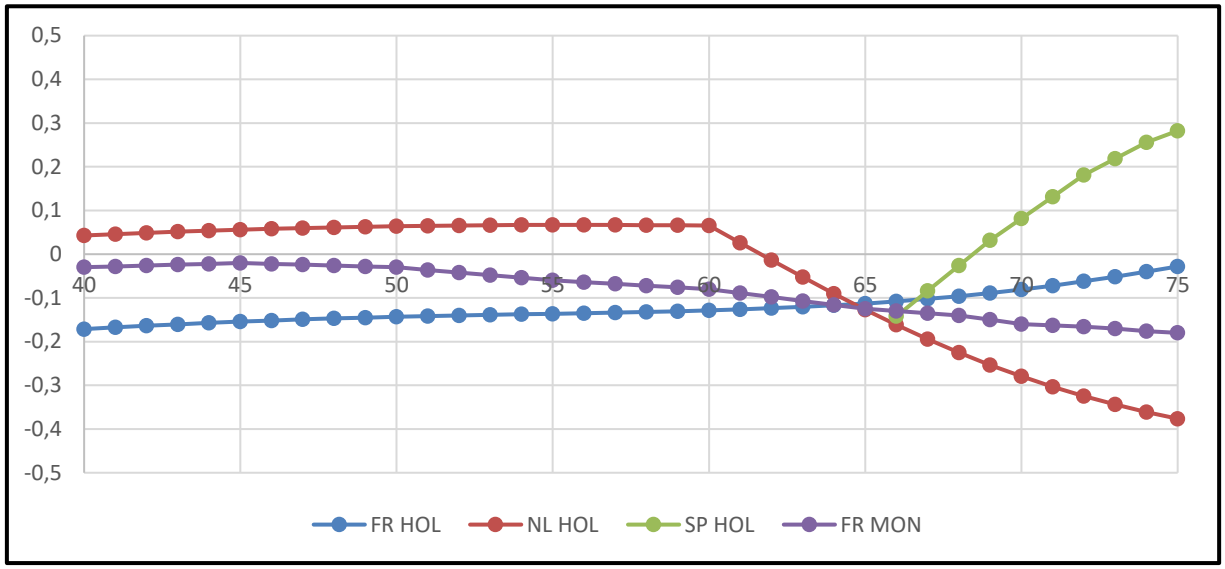
- In actual conditions, we observe **unfavourable genetic correlations** between **production and functional traits**.

- We may anticipate that these correlations will **become even more unfavourable** in future warmer conditions

- **Objectives**:
  - Predict the trade-offs in future conditions
  - Predict the effects of current selection

RUMIGEN WP3 – Predict trade-offs in future conditions

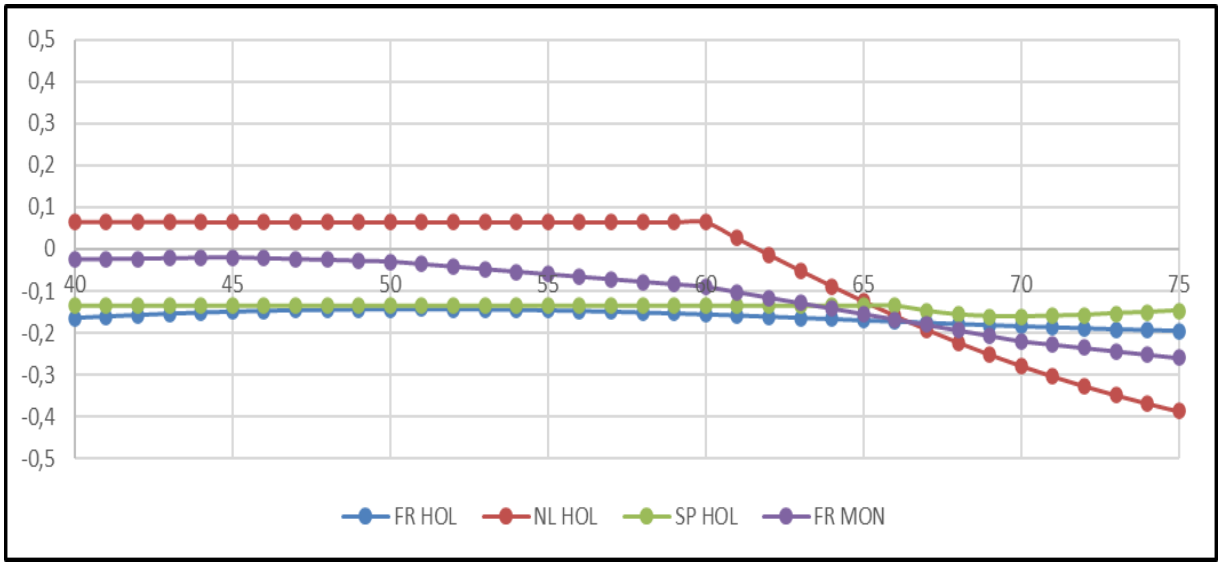
Trajectories of genetic correlations between protein yield and conception rate at the same THI



- **Results not fully consistent across populations**
  - Spain: possible acclimatation
  - France: remains more or less stable under heat stress conditions
  - The Netherlands: stronger unfavourable correlation
    could be an effect of the model
    or an indication that selecting for good production and good fertility will become more difficult in future conditions

RUMIGEN WP3 – Predict the effect of current selection

Trajectories of genetic correlations between PY at THI 50 and CR along the THI



- Current selection on production has a limited but negative impact on future reproduction abilities
  Stronger impact in the Netherlands than in France and Spain

➢ **Adapt the breeding objectives with higher weights for functional traits**

Impact of *in utero* heat stress

RUMIGEN WP3 – Impact of maternal heat stress on offspring performances

- **Objective:** Assess the impact of **heat stress at different stages of gestation** on milk production and conception rate in Holstein and Montbéliarde cows.

- **Key findings:**
  - **France**:
    - **Limited impacts** of maternal heat stress on progeny traits
      ≈ 1% of average 305day milk production
  - **Spain**:
    - Clearer evidences: **third-generation cows** showed **noticeable declines in fat and protein yields**, increasing with lactation number, when their dams, granddams, and/or great-granddams experienced heat stress during gestation
    - A **maternal environmental effect on cows' production traits** (**up to 8%** of the genetic variance), with an increase in impact according to the lactation number
  - **Both countries**:
    - **Negative impacts** of **early gestation heat stress** on offspring production, particularly protein and fat yields

Conclusion

RUMIGEN Main conclusions – Impact of heat stress on dairy cows performances and their progeny

- **Higher temperatures** will be **associated** with
  - **Decreased milk production**
  - **Increase risk of mastitis**
  - **Reduced reproduction performances**

- **Within-trait**, **few GxE interactions** were observed for **production and SCS** but they were **stronger for reproduction**
- **Variability between individuals**: some animals are more tolerant to heat stress

- Important to **adapt the breeding objectives** with higher weights on **functional traits** (health and reproduction)

- Impact of ***in utero*** **heat stress** : **variable magnitude** of the impact but results suggest **a negative effect of heat stress in early gestation**

RUMIGEN PARTNERS

Thank you for your attention

www.rumigen.eu

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101000226

Negative impact of an increasing THI on SCS in cows in 1st lactation