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DEGLI STUDI
FIRENZE

Genotype by environment interaction for growth traits in the Italian Limousine population

Simone Callegaro¹, Francesco Tiezzi¹, Maria Chiara Fabbri¹,
Christian Maltecca^{1,2}, Riccardo Bozzi¹

¹ *Department of Agriculture, Food, Environment, and Forestry,
University of Florence, Florence, Italy*

² *Department of Animal Science, North Carolina State University, Raleigh, United States*

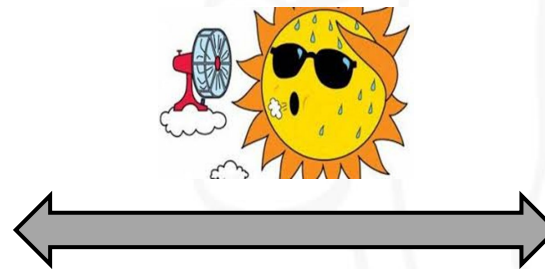
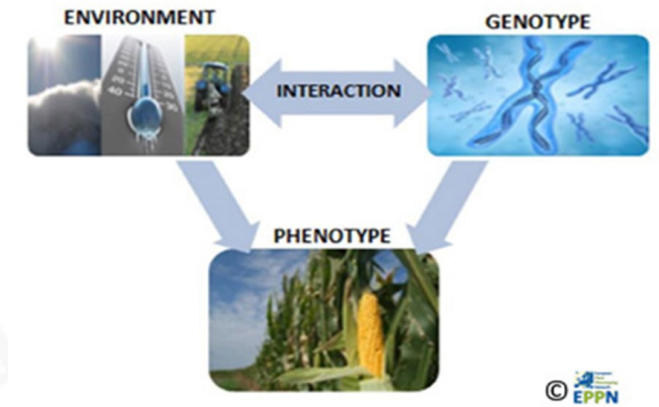
The new selection challenges at the livestock level focus on animal resilience.....



Given the increasing focus on animal welfare in recent years, genetic models will be developed for selective indices of animal resilience and welfare.

Why GxE and Heat Stress?

- Quantifying heat stress is one of the major challenges in animal breeding programs.
- Environmental conditions can dramatically change over space and time affecting animal productivity.

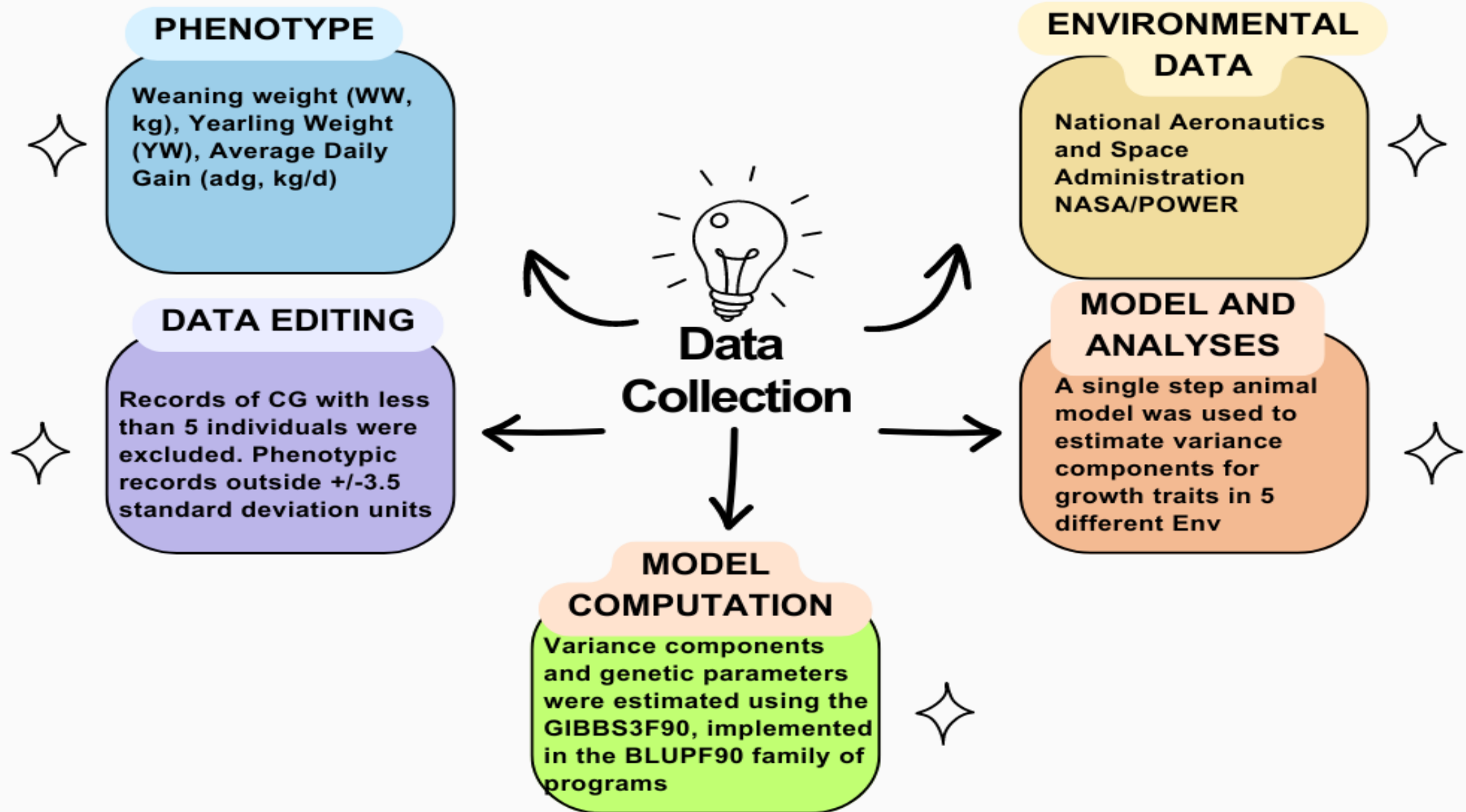


Objectives



This study aimed to investigate the genetic basis of tolerance to heterogeneous environmental conditions (GxE) and the impact of heat stress on genetic parameters in **Italian Limousine beef cattle**.

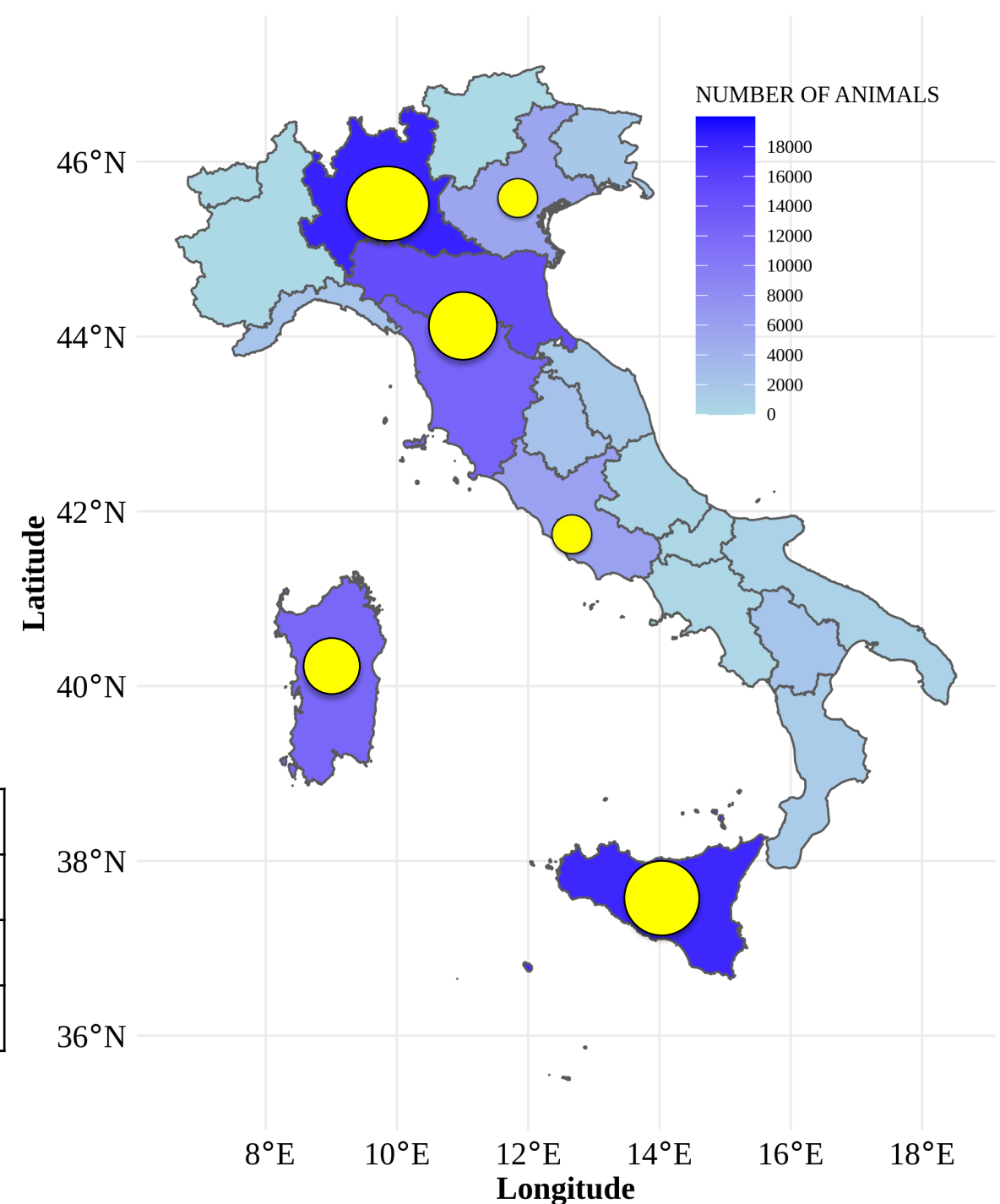




Data Collection

Number and distribution of Limousine breed animals with phenotype in the Italian regions.

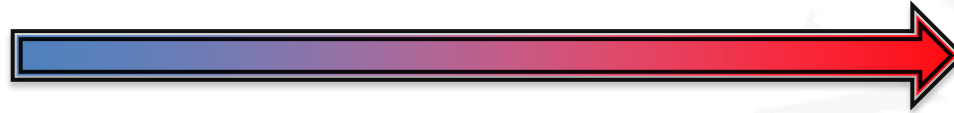
Traits	Animals	CG	Sires	Genotyped
ADG	108,205	5,712	3,783	4,617
WW	100,058	6,102	4,019	4,670
YW	24,939	2,030	2,162	2,048



Multiple-trait model (MTM)

Variance components and heritabilities estimation

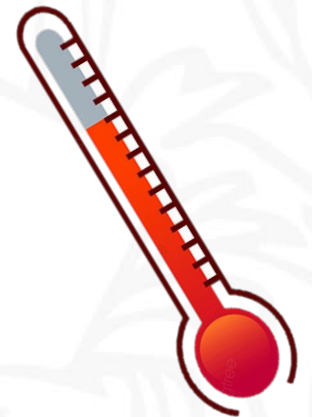
Through a **Multiple trait model (MTM)** analysis we estimated the genetic component in different environments to confirm the presence of GxE on animals' growth.



ID	Ebv T1	Ebv T2	Ebv T3	Ebv T4	Ebv T5
bull1	2.25	9.25	7.18	3.96	0.50
bull2	1.25	-7.87	-1.79	6.79	7.02
bull3	0.84	6.82	0.76	-0.90	-4.92
...	...	...	...	...	...

Temperature:

T1 < 7 °C;
T2 = 7-12 °C;
T3 = 12-17 °C;
T4 = 17-23 °C;
T5 > 23 °C.



Multiple-trait model

Variance components and heritabilities estimation

Multiple-trait model:

- GxE for growth traits
- 1 Breed
- Single Step GBLUP

$$\mathbf{H}^{-1} = \mathbf{A}^{-1} + \begin{bmatrix} 0 & 0 \\ 0 & \mathbf{G}^{-1} - \mathbf{A}_{22}^{-1} \end{bmatrix}$$

- y : phenotype (ADG, WW, YW)
- $\mathbf{X}\beta$: fixed effect of sex, age of animals, age of dam in five classes
- $\mathbf{Wm}$: random effect of herd-year (CG)
- $\mathbf{Za}$: additive genetic effect
- e : residual error

$$y = \mathbf{X}\beta + \mathbf{Za} + \mathbf{Wm} + e$$



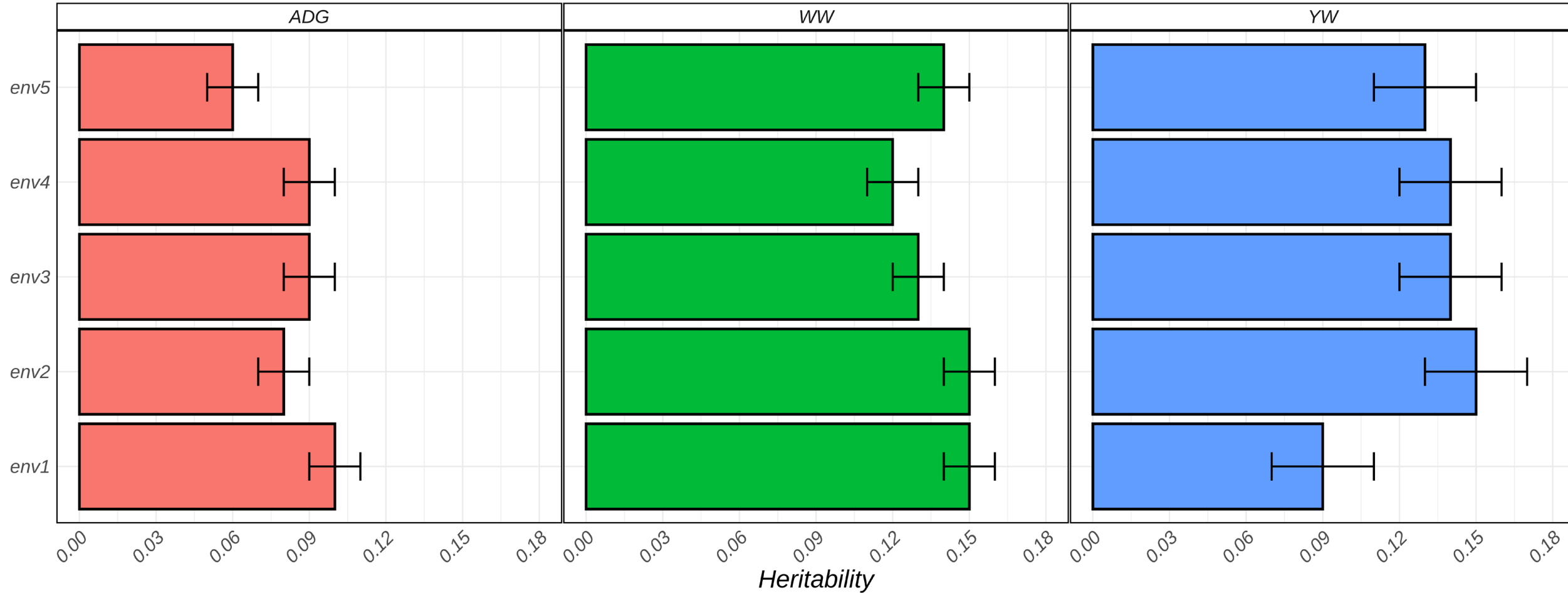
$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{X}_2 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{X}_3 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{X}_4 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{X}_5 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_1 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{Z}_2 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{Z}_3 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{Z}_4 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{Z}_5 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} +$$

$$\begin{bmatrix} \mathbf{W}_1 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{W}_2 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{W}_3 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{W}_4 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{W}_5 \end{bmatrix} \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \end{bmatrix}$$

Results: Variance components

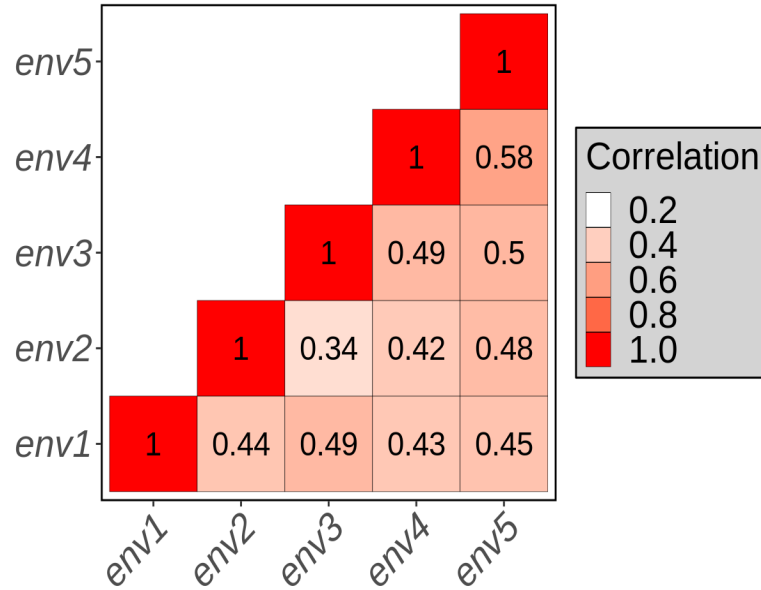
Trait	Environment	σ_a^2
ADG	Env 1	<u>0.008</u>
	Env 2	0.006
	Env 3	0.007
	Env 4	0.007
	Env 5	<u>0.005</u>
WW	Env 1	<u>249.94</u>
	Env 2	260.47
	Env 3	<u>222.49</u>
	Env 4	<u>203.79</u>
	Env 5	<u>233.05</u>
YW	Env 1	<u>273.27</u>
	Env 2	492.47
	Env 3	<u>457.01</u>
	Env 4	514.62
	Env 5	<u>421.64</u>

Results: Heritability

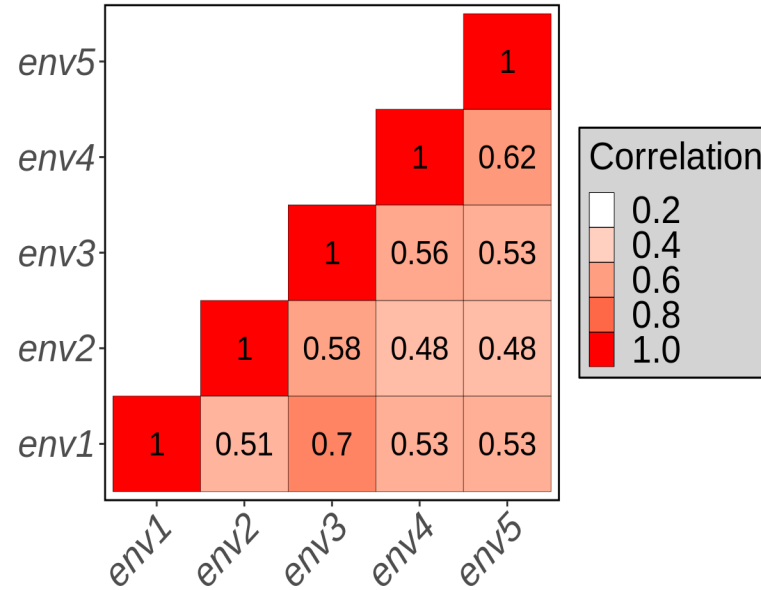


Results: Genetic correlations

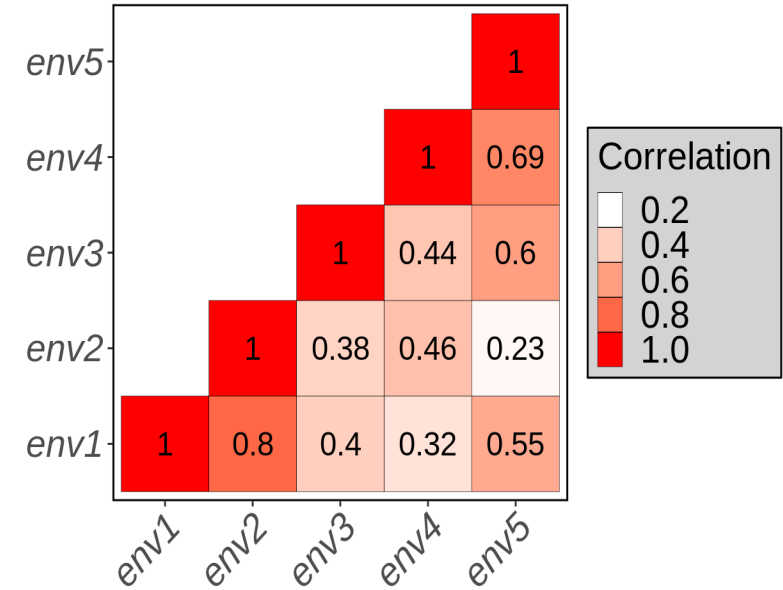
Average daily gain - Single Step GBLUP



Weaning weight - Single Step GBLUP

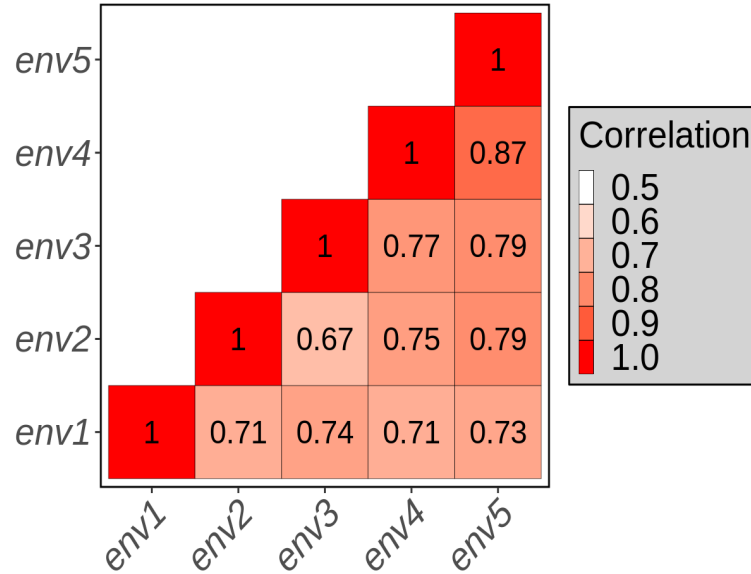


Yearling weight - Single Step GBLUP

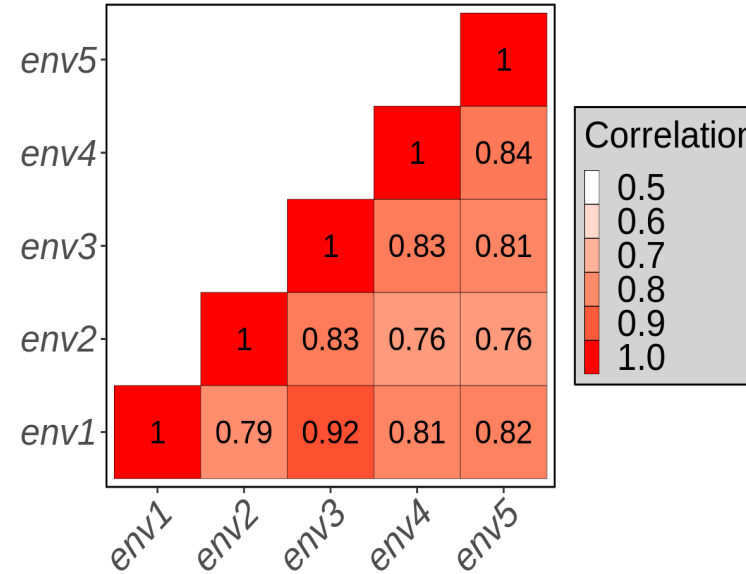


Results: Spearman correlations

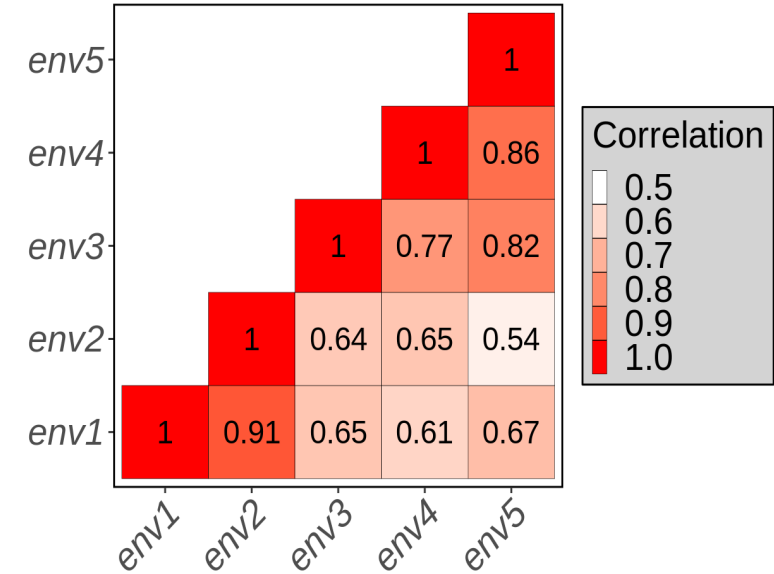
Average daily gain - Single Step GBLUP



Weaning weight - Single Step GBLUP



Yearling weight - Single Step GBLUP





01. Results

1) Substantial heterogeneity was observed in heritabilities and variance components for growth traits in different environments, indicating different degrees of genetic control for heat tolerance in the Limousine population



01. Results

2) As evidence of GxE genetic correlation lower than 0.80 between Environments was found for ADG, WW, and YW



01. Results

3) Spearman correlation confirms possible re-ranking between sires. Indeed, the best animals in less stressful environments are not necessarily the best animals in more stressful environments

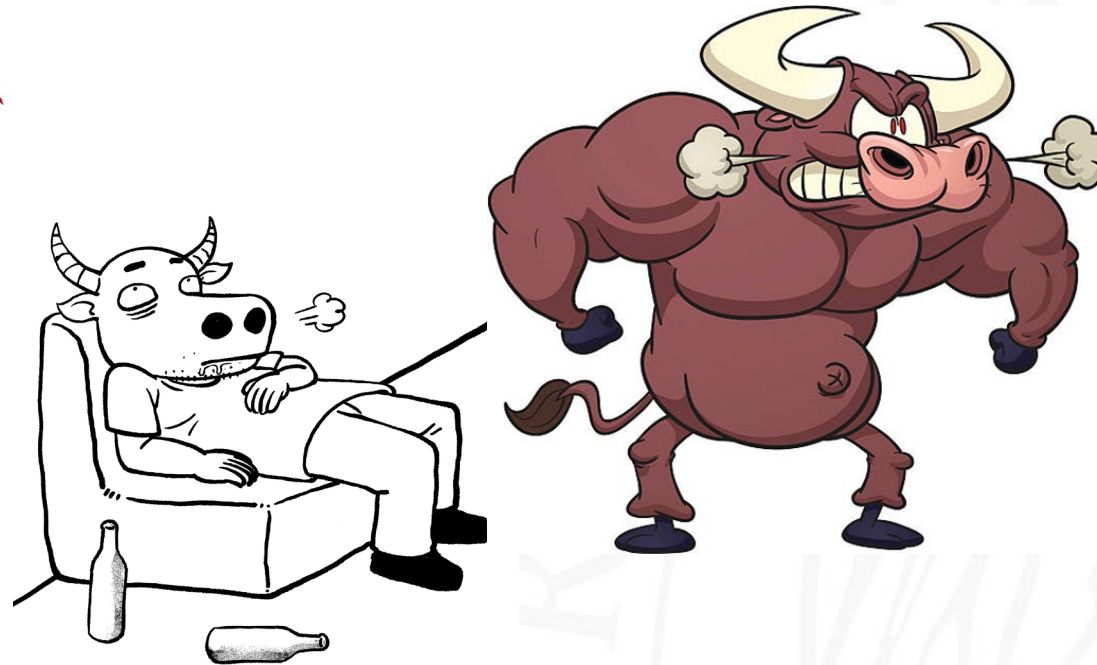
Resilience

Acclimatation

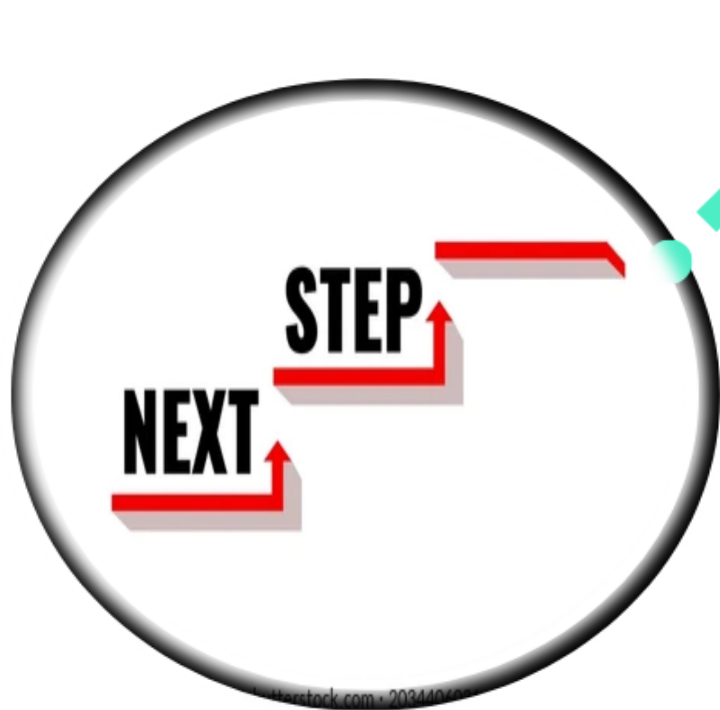
Robustness

Plasticity

Tolerance



Future Challenges



0.2 Further Research

1. Further research is needed to better understand the genetic and genomic background of heat tolerance and the genetic mechanism of adaptability in beef cattle.
2. Future analyses could explore this aspect by implementing a random regression model. When multiple environmental covariates are present, multidimensional environmental data can be incorporated using Reproducing Kernel Hilbert Spaces regression



Thank you for your attention



Acknowledgments

The research was funded by ANACLI through the I-BEEF2 project PSRN 2014–2020.

Sottomisura 10.2: Biodiversità animale. We acknowledge Associazione Nazionale Allevatori delle razze bovine Charolaise e Limousine (ANACLI) for providing the data.

Environmental Parameters the National Aeronautics and Space Administration (NASA/POWER, <https://power.larc.nasa.gov>)

- Averaged daily temperature (T °C);
- Dew point (DP, °C Td);
- Relative Humidity (RH, %)
- Heat Load (HL) $\rightarrow HL70 = \max(0, \sum THI - 70)$;
- Temperature Humidity Index (THI) $\rightarrow THI = (1.8 \times AT) - (1.0 - RH) * (AT - 14.3) + 32$;
- **Five classes using quintiles per each variables.**



Linear mixed model

The effect of the environmental covariates on ADG, WW, and YW was assessed by implementing the subsequent linear mixed model:

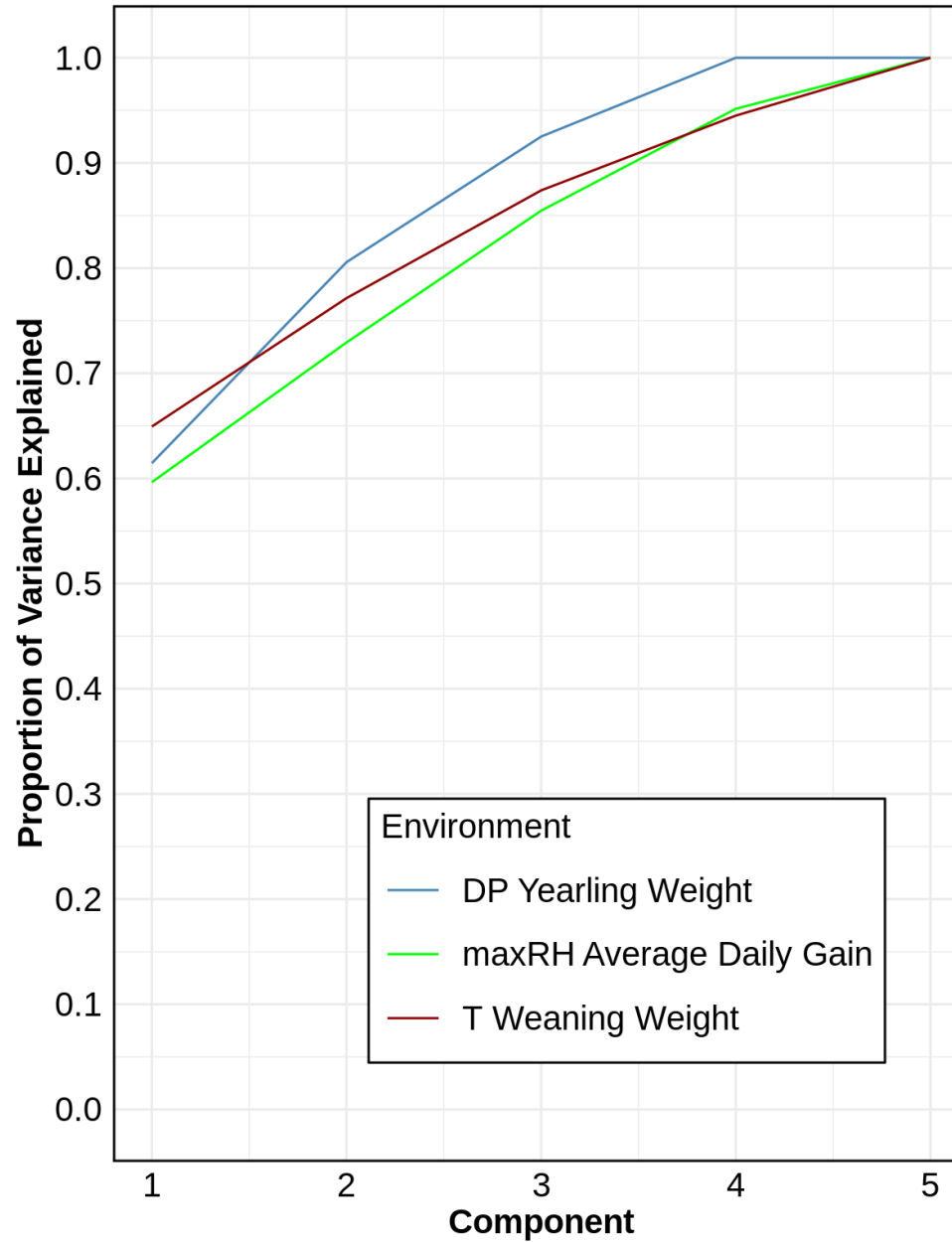
$$y_{ijklmno} = \mu + env_j + brd_k + sex_l + age_m + AgeDam_class_n + hy_o + e_{ijklmo}$$

Data Collection

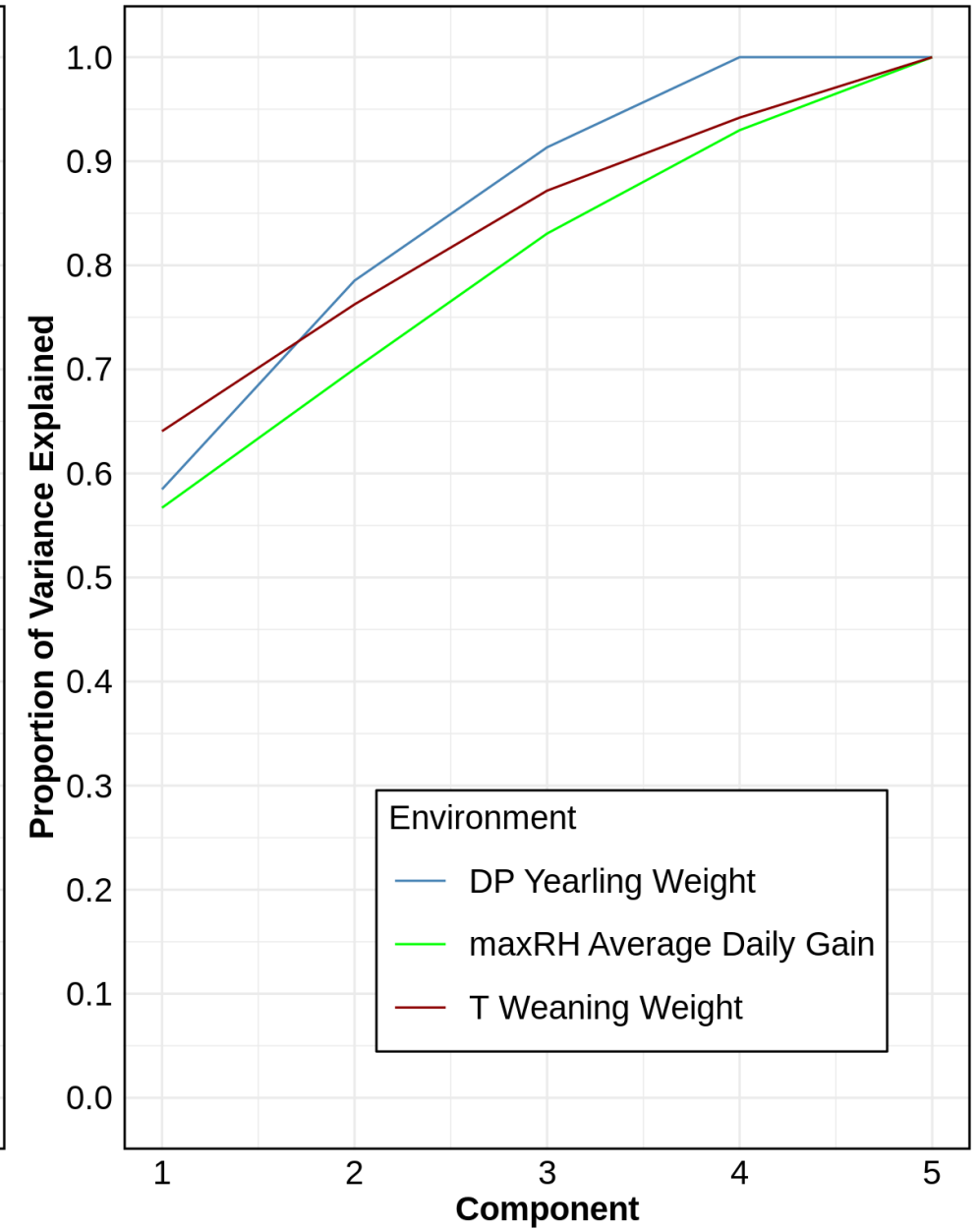
Growth traits records in population

Traits ¹	Covariate ²	Interval	Environment	N
ADG	maxRH_CLASS	[40.69 - 72.44]	Env 1	21,778
	maxRH_CLASS	(72.44 - 79.12]	Env 2	21,540
	maxRH_CLASS	(79.12 - 84.92]	Env 3	21,619
	maxRH_CLASS	(84.92 - 89.94]	Env 4	21,753
	maxRH_CLASS	(89.94 - 98.70]	Env 5	21,515
WW	T_CLASS	[-11.31 - 7.41]	Env 1	19,999
	T_CLASS	(7.41 - 12.35]	Env 2	20,024
	T_CLASS	(12.35 - 17.45]	Env 3	20,021
	T_CLASS	(17.45 - 22.72]	Env 4	20,002
	T_CLASS	(22.72 - 35.66]	Env 5	20,012
YW	DP_CLASS	[-8.65 - 3.88]	Env 1	4,990
	DP_CLASS	(3.88 - 7.17]	Env 2	4,985
	DP_CLASS	(7.17 - 10.25]	Env 3	4,992
	DP_CLASS	(10.25 - 13.89]	Env 4	4,984
	DP_CLASS	(13.59 - 23.15]	Env 5	4,988

G x E Multiple Trait - Pedigree BLUP



G x E Multiple Trait - Single Step GBLUP



Yearling Weight - Pedigree BLUP

