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Sustainable Dairy Farming- A Case Study of Holsteins in a Developed and Emerging Country

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Context

- Drivers of change in animal production:
  - Purchasing power
  - Urbanization
  - Consumer preference
- Exchange / acceleration of gene flow

- Efficiency and sustainability depends:
  - genotype response
  - Breeders capacity
- Genotype by environment interaction (**GxE**)

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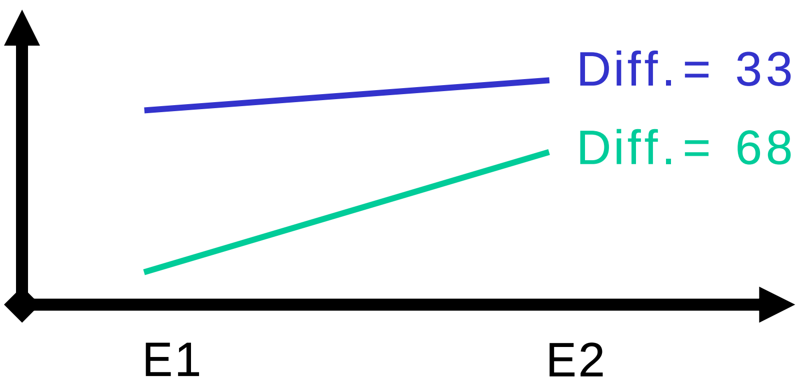
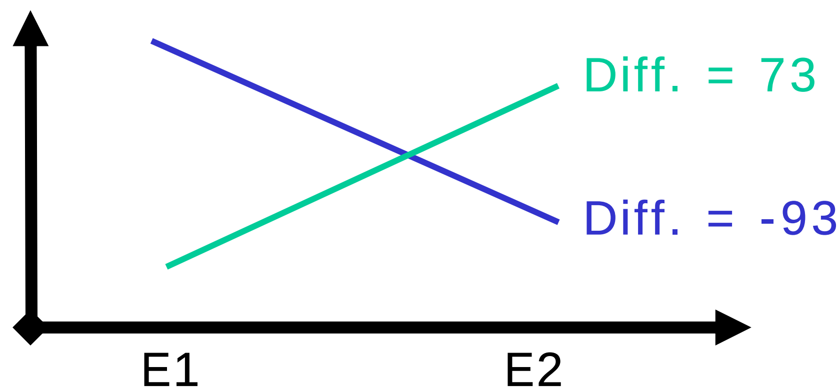
GxE: Ability to alter phenotype to environmental changes

Diff = genetic value (E2) – genetic value (E1)



Scaling effect



Re-ranking

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General objective

Quantify the effectiveness of genetic response from indirect selection of Holsteins using two countries as model:

Luxembourg (high input system)

and Tunisia (low- to medium-input system)

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Luxembourg

- Holsteins: predominant (90% milk recording)
- EU enlargement, CAP reform, and WTO
- Decoupling and prices cuts → production systems diversification is necessary
- Transition from one system to another
  - Adaptability and reaction of genotypes
  - Avoid harmful environmental effects

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Tunisia

- Dairy milk production enhancement:
  - importation of Holsteins since 1960
    - Heifers (3000 h/year)
    - Semen (250 000 s/year)
  - factories and cooperatives for milk collect and marketing
- Some satisfactory performances but sensible to integrated livestock-farming
- Selection should consider local production circumstances and environmental sensitivity

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Materials & Methods

- Data set

	Luxembourg	Tunisia
Test-day	661,453	281,913
Cows	77,814	36,211
Herds	525	108

- 231 common sires
  - 14,421 daughters (LUX): 19%
  - 6,358 daughters (TUN): 18%
- Genetic similarity : 0.19
- Average additive relationships (>2.2%)

Hammami et al., 2007

Materials & Methods

- Analysis
  - Country-side approach (Hammami et al., 2008)
    - Whole country = character state
  - Specific-environment (**SPE**) approach
    - Herd management level
    - 3 different environment / country = 3 traits / country (Hammami et al., 2009)

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Materials & Methods

- Country-side approach
  - Bivariate analysis (sire and animal RRM)
  - Variance component estimation (Gibbs sampling)
    - heritability
    - Genetic correlation (r_g)
  - Genetic evaluation:
    - rank correlation between EBVs of all common sires (r_b)
    - Curve of EBV for the top 5 bulls
  - Traits studied:
    - Daily milk yield (**DMY**)
    - 305-d milk yield (**305-d MY**)
    - Persistency (EBV_{280}-EBV_{80})

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Materials & Methods

- SPE approach
  - Identification of SPE:
    - Herd management level = solutions “herd-testdate” + “herd-year”
    - Clustering method (3 SPE retained per country)
      - **HI**: high **MI**: Medium and **LO**: low level
  - Multi-trait random regression model
    - r_g and r_b between pairs of contrasted SPE
  - Differential selection
    - Identification of TOP20 from national evaluation
    - Identification of TOP20 from each SPE evaluation
    - Comparison between rankings of the national and SPE evaluation

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Materials & Methods

Models:

Fixed effects:

- Herd x test-date
- Class of 25 DIM nested in age by season of calving
- Class of 5 DIM

Random effects:

- Herd x year of calving (**HY**)
- Permanent environment (**PE**)
- Additive genetic (**AG**)
- Residuals

(HY, PE and AG: Fourth order Legendre Polynomials)

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Results

Country-side approach

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Production descriptive parameters

Parameter	LUX	TUN
DMY (kg)	21.8	18.0
Peak yield (kg)	27.5	23.9
Days to peak (day)	73	65
Age at calving (month)	31	29
305-d MY (kg)	7,946	6,220
Calving interval (day)	401	444

Milk production level differ significantly between the 2 countries

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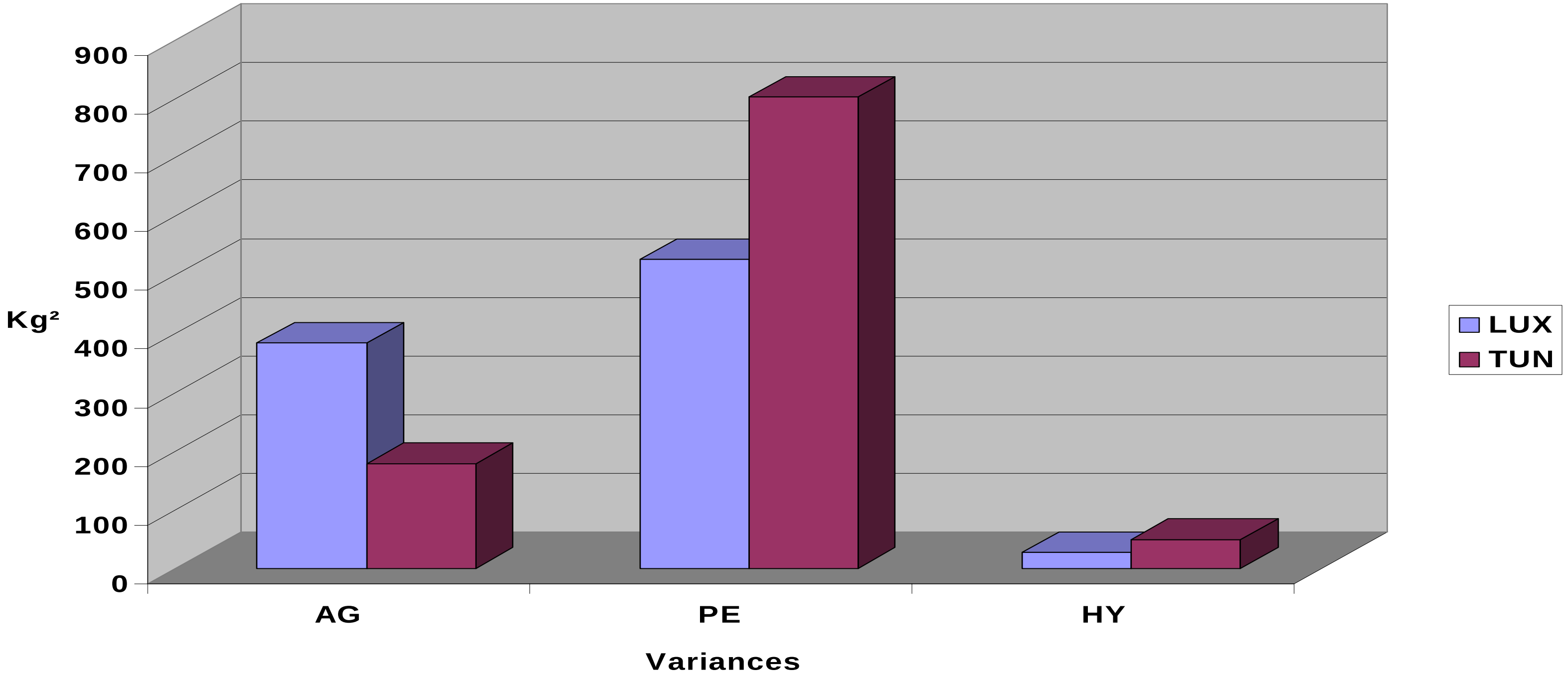
Variances



- ✓ Reduced AG → difficultly for expressing genetic potential
- ✓ largest EP → additional variation due poor management practices and feeding fluctuations

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Genetic parameters

Country / Trait	heritability		r_g	r_b
	LUX	TUN		
305-d MY	0.42	0.19	0.60	0.41
Persistency	0.12	0.08	0.36	0.26

✓ **Differences in h² for MY may be caused by differences in production levels**
✓**Low h² for persistency → suppressing expression of genetic variation**
✓**Low r_g (<0.80) → significant GxE and a re-ranking of sires**

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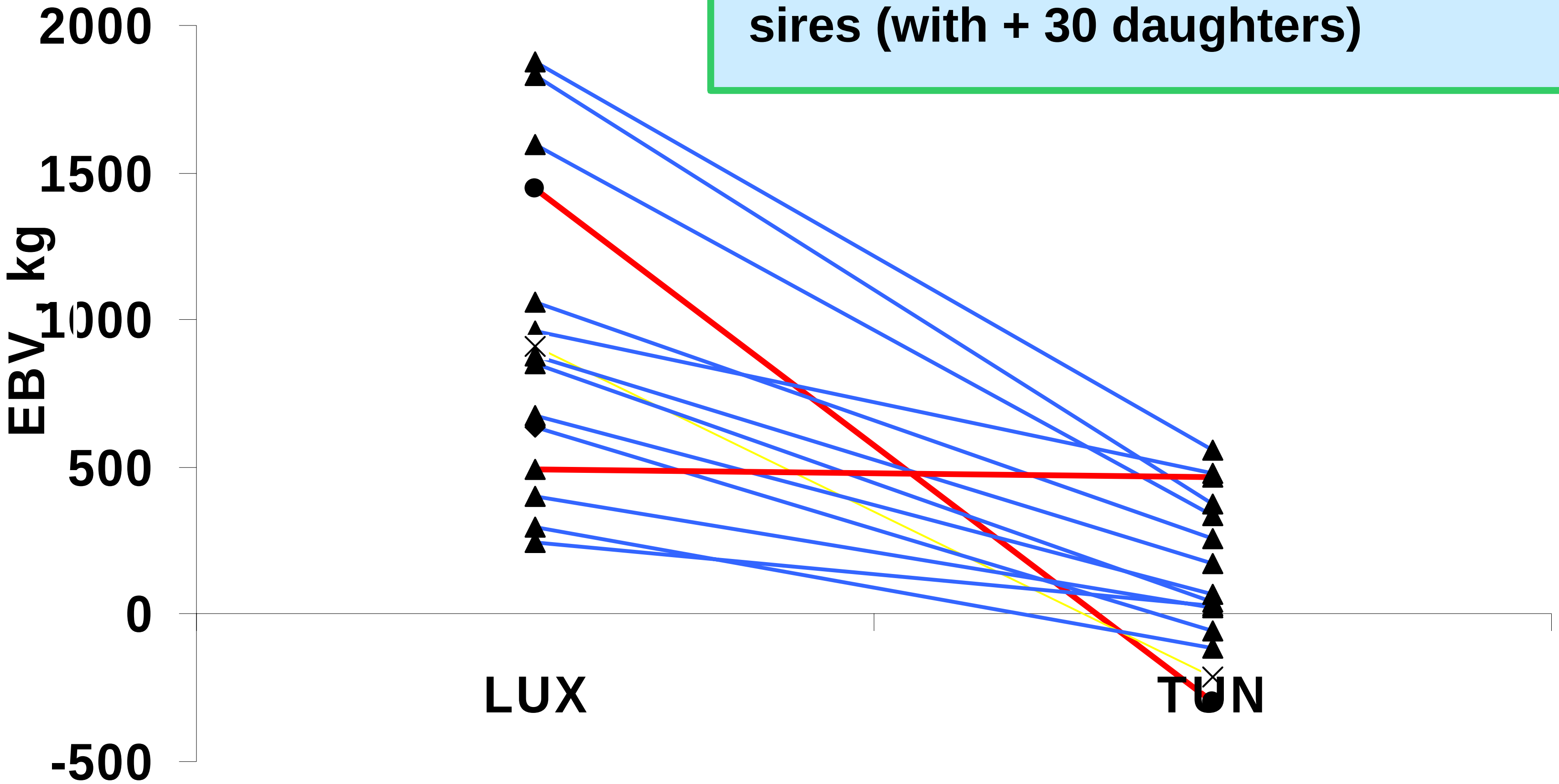
EBVs of common sires

305-d MY

Considerable re-ranking of common sires (with + 30 daughters)



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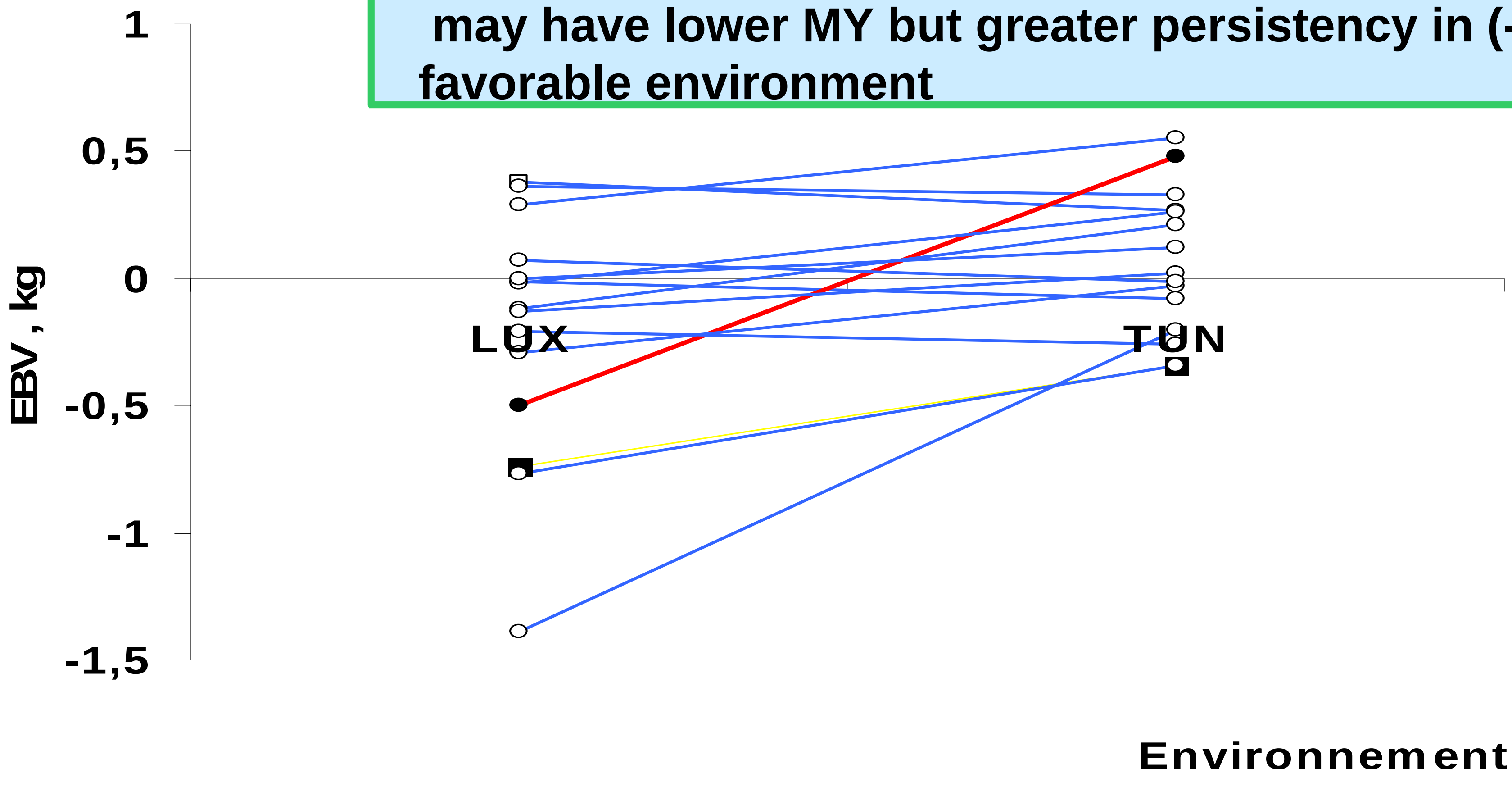
EBVs of common sires

Persistency

animals with (+) EBV for MY in best environment may have lower MY but greater persistency in (-) favorable environment



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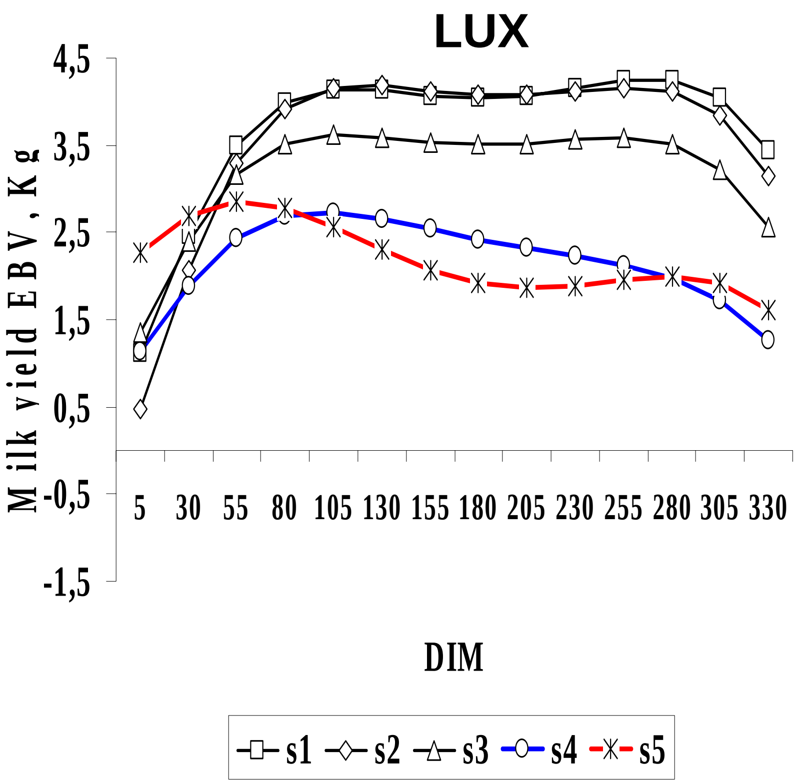
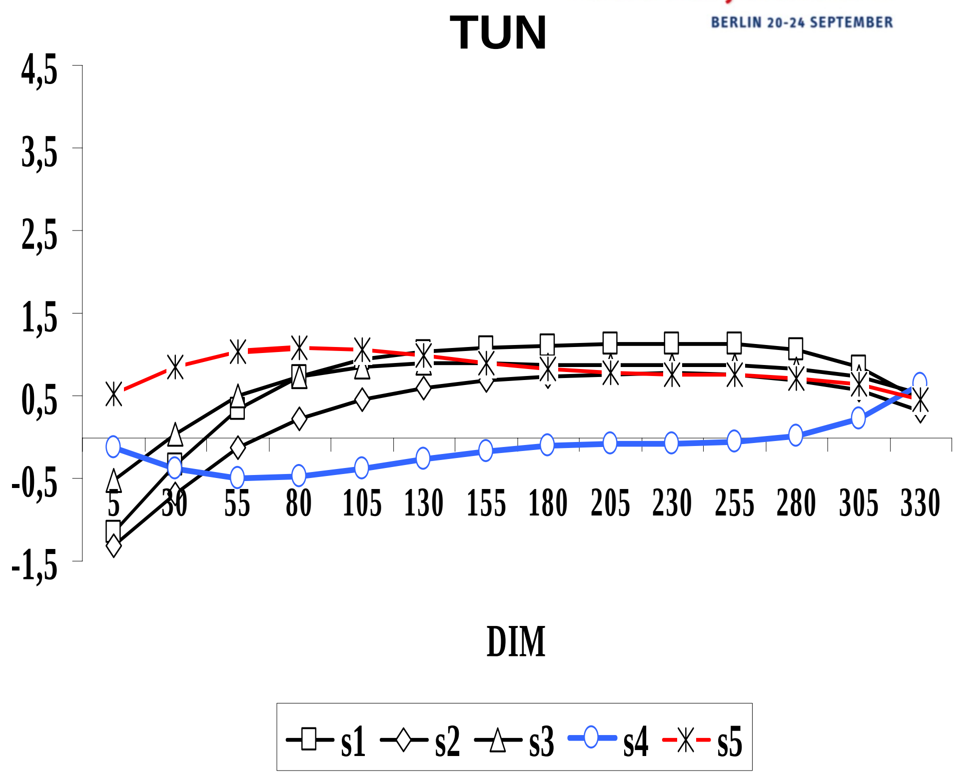
EBVs curve of TOP 5





- ✓ **Difference in genetic expression throughout the lactation**
- ✓ **Re-ranking of common sires was important across the lactation**

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Results

SPE approach

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Descriptive parameters

	LUX			TUN		
	HI	MI	LO	HI	MI	LO
HM (kg)	9.6	6.8	4.2	6.8	5.9	4.5
DMY (kg)	25.5	22.4	19.5	21.6	17.7	13.7
305-d MY	7,917	7,017	6,086	7,375	5,462	4,623
Age (mo)	29	31	32	29	31	29

- ✓ **MY levels decrease from HI to LO levels**
- ✓ **TUN HI have similar MY levels as MI and LO LUX herds**
- ✓ **HM level varie with milk production level**

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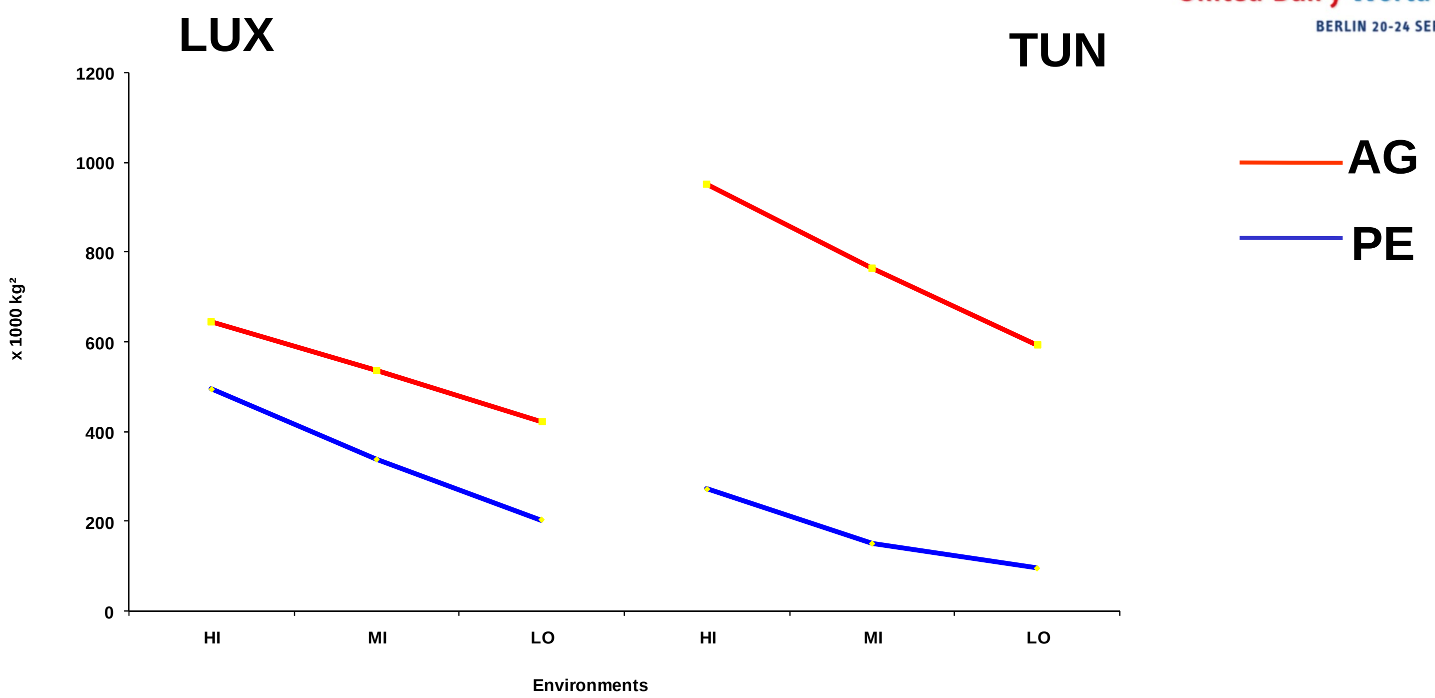

AG and PE variances decreased from HI to LO HM level in both countries

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Genetic parameters

Parameter		LUX HI	LUX MI	LUX LO		TUN HI	TUN MI	TUN LO
LUX	HI	**0,41**	**0,98**	**0,97**		0,61	0,43	0,39
	MI	**0,82**	**0,37**	**0,97**		**0,79**	0,70	0,43
	LO	**0,76**	**0,83**	**0,31**		**0,77**	0,67	0,55
TUN	HI	0,41	0,43	0,26		**0,21**	**0,78**	**0,70**
	MI	0,38	0,34	0,23		**0,42**	**0,15**	**0,73**
	LO	0,26	0,39	0,19		**0,33**	**0,37**	**0,12**

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Genetic parameters

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LUX	HI	**0,41**	0,98	0,97	0,61	0,43	0,39
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TUN	HI	0,41	0,43	0,26	**0,21**	0,78	0,70
	MI	0,38	0,34	0,23	0,42	**0,15**	0,73
	LO	0,26	0,39	0,19	0,33	0,37	**0,12**

- ✓ h^2 vary with the HM level in both countries
- ✓ h^2 were larger in the 3 LUX SPE
- ✓ Large h^2 in HM level reflect the high AG compared to LO levels

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Genetic parameters

Parameter		LUX				TUN		
		HI	MI	LO		HI	MI	LO
LUX	HI	0,41	**0,98**	**0,97**		0,61	0,43	0,39
	MI	**0,82**	0,37	**0,97**		0,79	0,70	0,43
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TUN	HI	0,41	0,43	0,26		0,21	**0,78**	**0,70**
	MI	0,38	0,34	0,23		**0,42**	0,15	**0,73**
	LO	0,26	0,39	0,19		**0,33**	**0,37**	0,12

- ✓ **LUX: r_g >0.96 suggest that sires rank similarly in the different SPE**
- ✓ **Differences in variances → scaling effect**
- ✓ **TUN: r_g <0.80 associated with low rb → high potential of re-ranking**

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Genetic parameters

Parameter		LUX HI	LUX MI	LUX LO		TUN HI	TUN MI	TUN LO
LUX	HI	0,41	0,98	0,97		0,61	0,43	0,39
	MI	0,82	0,37	0,97		**0,79**	0,70	0,43
	LO	0,76	0,83	0,31		**0,77**	0,67	0,55
TUN	HI	0,41	0,43	0,26		0,21	0,78	0,70
	MI	0,38	0,34	0,23		0,42	0,15	0,73
	LO	0,26	0,39	0,19		0,33	0,37	0,12

- ✓ **Lowest r_g were observed between HI LUX and the 3 TUN SPE**
- ✓ **MI and LO LUX well correlated to HI TUN herds**
- ✓ **Daughters (MI and LO LUX) good predictors to their half-sisters (HI TUN)**

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EBV TOP20: LUX

National	HI	LO
S1	S1	S3
S2	S2	S2
S3	S4	S1
S4	S5	S4
S5	S3	S5
S6	S6	S9
S7	S8	S7
S8	S7	S8
S9	S9	S6
S10	S10	S10
S11	S13	S11
S12	S12	S12
S13	S11	S23
S14	S14	S27
S15	S15	S22
S16	S17	S20
S17	S16	S24
S18	S18	S28
S19	S26	S19
S20	S24	S20

- **The best national 20 sires were also almost the same best sires in HI (18/20) and LO (12/20) SPE**
- **So, breeders may use sires in various HM levels without great risks**

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EBV TOP20: TUN

National	HI	LO
S1	S1	S16
S2	S2	S18
S3	S4	S26
S4	S5	S24
S5	S3	S25
S6	S11	S29
S7	S8	S27
S8	S10	S38
S9	S9	S37
S10	S13	S41
S11	S16	S23
S12	S12	S31
S13	S6	S33
S14	S7	S22
S15	S15	S28
S16	S14	S42
S17	S21	S36
S18	S28	S49
S19	S26	S30
S20	S24	S40

- **Ranking of sires changed between national and SPE. (16/20) in HI but only (2/10) for LO**
- **Semen exchange between the different SPE should be done with great caution.**

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Magnitude of GxE

- Country-side approach
  - AG variances: 60% reduced in Tunisia
  - h^2 305-d MY :73 to 78%
  - r_g 305-d MY (0.60); Persistency (0.43)
  - high re-ranking
- SPE approach
  - LUX : Only scaling effects (r_g >0.96)
  - TUN : re-ranking (low r_g and r_b)
  - r_g (LO LUX vs HI TUN) ≅ 0.80

genetic expression depend highly on the input levels

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Implications

Breeding programs sustainability

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High-input systems

- Production levels = proportionate to HM levels → direct selection
- Only one national list of EBV but have to absorb the scaling effect
- Fertility and functional traits: only scaling effect
- Correction and use average economic → only one national composite index
- No need to select a specific genotype for SPE
- Challenge in production systems require new selection criterion

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High-input systems

- Factors affecting sustainability:
  - Deterioration of fertility (Liu et al.,2008)
  - Limitation of the net profit (Conter, 2008)
    - Shortage in farm land
    - High quota prices
    - High level of fixed costs
  - Energy consumption + CO_2 emissions (30 t/a per head) (Stoll, 2008)
  - Over-consumption of animal based diets (300 kg animal products = x2 much as needs) (Stoll, 2008)

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High-input systems

- Consumption reduction of animal products
- Economic profitability:
    - increasing farm sizes
    - decreasing direct costs
    - moving to semi-intensive and extensive systems
- Reducing herd sizes (greenhouse gaz)
- By means of pastureland based feeding :
    - healthier fine component
    - organic manner
    - less competitor for human food

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Low- to medium-input systems

- r_g <0.60 + hampered genetic expression → limited response to indirect selection
- Equitably balance between gene importation and local progeny testing:
  - HI: straight-breeding to improve exotic breeds
  - LO: cross-breeding more efficient
- Breeding goals, resources requirements and organizations should be discussed
- Extension of milk recording and ID registration
- genetic evaluation model appropriate to SPE conditions

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Low- to medium-input systems

- Factors affecting sustainability:
    - Limited genetic expression for major traits
    - Extensive to even ‘a road side’ system
        - out-land purchased products
        - Disproportional: herd sizes / arable areas
        - Poor nutrition, management skills and forages availability → Low yields, fertility, and survival
        - Lack of farmer associations
    - Integrated intensive systems
        - Large-scale farms with high fixed costs (machinery, fuel, concentrates)
        - threat to environment and human heath
        - Require expensive costs to enhance heat stress and management practices (cooling, management surveys)

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Low- to medium-input systems

- Smallholder production:
  - Efficiency of dairy cows is to be redefined with respect to:
    - Valorization of scare sources
    - Adaptation to stressful local conditions
    - Survival under use of limited capital, labor, and heath services
    - Valorization of non-marked benefits
  - Local and cross breed cows may replace Holsteins under the harsh edapho-climatic conditions

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Low- to medium-input systems

- Integrated intensive systems:
  - Dress a good relation between animal requirements and farm system potentialities
    - Forage production intensification and diversification
    - Redesign farm units and production levels
    - Maintain an even-year production for at least 4 lactations
  - Increase the capacity for organizing and monitoring the breeding sector
    - Improvement of the degree of involvement of key operators
    - Breeding objectives should focused on maintaining a cost effective production levels under local conditions
    - Implantation of genetic evaluation system integrating major traits and favoring adaptation to local conditions

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Conclusions

- Scaling effect (high-input) *vs* re-ranking (low-input)
- Selection under less intensive systems (ruminants preferences, welfare and environment preservation)
- Low input: selection for adaptive traits under specific conditions
- Improvement of management conditions and husbandry practices for exotic breeds
- Use diverse genetic resources with potentials for production, adaptation, and resistance to heat stress and diseases

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Thank you for your attention

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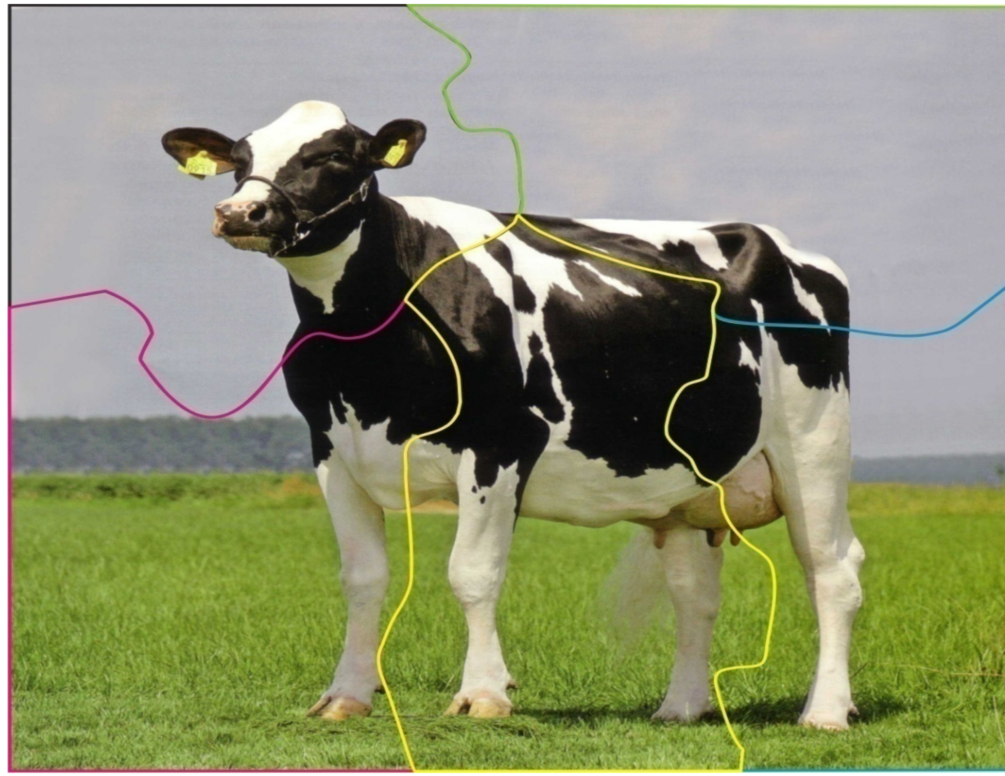

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Sustainable Dairy Farming- A Case Study of Holsteins in a Developed and Emerging Country

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