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)
GxE: Ability to alter phenotype to environmental changes

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

Scaling effect

Re-ranking
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)
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
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
Materials & Methods

- Data set

  - Luxembourg
  - Tunisia
  - Test-day: 661,453
  - Cows: 77,814
  - Herds: 525

- 231 common sires

- Genetic similarity: 0.19

- Average additive relationships (>2.2%)

  - 14,421 daughters (LUX): 19%
  - 6,358 daughters (TUN): 18%

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)
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 ($\text{DMY}$)
  - 305-d milk yield ($\text{305-d MY}$)
  - Persistency ($\text{EBV}_{280-EBV}_{80}$)
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
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)

Fourth order Legendre Polynomials

Residuals
Results

Country-side approach
Production descriptive parameters

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

Milk production level differ significantly between the 2 countries
Variances

✓ Reduced AG → difficulty for expressing genetic potential
✓ largest EP → additional variation due poor management practices and feeding fluctuations
## Genetic parameters

<table>
<thead>
<tr>
<th>Trait</th>
<th>heritability</th>
<th>Country</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>LUX</td>
<td>TUN</td>
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</tr>
<tr>
<td>305-d MY</td>
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<td>0.42</td>
<td>0.19</td>
<td>0.60</td>
<td>0.41</td>
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<tr>
<td>Persistency</td>
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<td>0.12</td>
<td>0.08</td>
<td>0.36</td>
<td>0.26</td>
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</tbody>
</table>

- Differences in $h^2$ for MY may be caused by differences in production levels
- Low $h^2$ for persistency $\rightarrow$ suppressing expression of genetic variation
- Low $r_g$ (<0.80) $\rightarrow$ significant GxE and a re-ranking of sires
EBVs of common sires

305-d MY

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

Persistency

animals with (+) EBV for MY in best environment may have lower MY but greater persistency in (-) favorable environment
Difference in genetic expression throughout the lactation
Re-ranking of common sires was important across the lactation
Results

SPE approach
### Descriptive parameters

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<tr>
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<th>LUX</th>
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<tbody>
<tr>
<td></td>
<td>HI</td>
<td>MI</td>
</tr>
<tr>
<td>HM (kg)</td>
<td>9.6</td>
<td>6.8</td>
</tr>
<tr>
<td>DMY (kg)</td>
<td>25.5</td>
<td>22.4</td>
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<tr>
<td>305-d MY</td>
<td>7,917</td>
<td>7,017</td>
</tr>
<tr>
<td>Age (mo)</td>
<td>29</td>
<td>31</td>
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</tbody>
</table>

- 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
AG and PE variances decreased from HI to LO HM level in both countries.
### Genetic parameters

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- $h^2$ 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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- LUX: \( r_g > 0.96 \) suggest that sires rank similarly in the different SPE
- Differences in variances \( \rightarrow \) scaling effect
- TUN: \( r_g < 0.80 \) associated with low \( r_b \) \( \rightarrow \) high potential of re-ranking
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<td>HI</td>
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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)
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

<table>
<thead>
<tr>
<th>National</th>
<th>HI</th>
<th>LO</th>
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<tbody>
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<td>S1</td>
<td>S1</td>
<td>S16</td>
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- 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.
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) $\approx 0.80$

**genetic expression depend highly on the input levels**
Implications

Breeding programs sustainability
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
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 + CO₂ emissions (30 t/a per head) (Stoll, 2008)
  - Over-consumption of animal based diets (300 kg animal products = x2 much as needs) (Stoll, 2008)
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
Low- to medium-input systems

- \( r_g < 0.60 \) + hampered genetic expression \( \rightarrow \) 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
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 health
    - Require expensive costs to enhance heat stress and management practices (cooling, management surveys)
Low- to medium-input systems

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

Acknowledgments

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Grand-Duché de Luxembourg

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