Effect of combining controlled natural mating with artificial insemination on the genetic structure of the flock book of Sardinian breed sheep

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Selection scheme of the Sardinian breed

Selection Objectives:

- **milk yield.** Since 1992 breeding values have been estimated by BLUP methodology applied to a repeatability animal model (Sanna et al., 1994, Carta et al., 1998a).

- **fat and protein content.** Since 1998 recordings on primiparous ewes have been realized. Milk composition is not yet considered as breeding goal due to the lack of a payment system of milk adequate to refund farmers for the possible loss of genetic progress on milk yield.

- **udder morphology.** Since 2004, breeding values for teat placement and degree of udder suspension have been estimated by BLUP methodology (Casu et al., 2006).

- **Scrapie resistance.** Introduced in 2004 (Salaris et al., 2007).
**SELECTED POPULATION**
8% of the whole population

- Official milk recording
- Artificial Insemination
- Controlled Natural Mating
- BV estimation

**Diffusion of genetic gain by natural mating rams**

**COMMERCIAL FLOCKS**
3,600,000 heads; 13,000 flocks

- One out-of-season lambing period per year
- Lambing period of mature ewes between October and December
- Lambing period of primiparous between February and March
- Lambs slaughtered after 30 days
- Milk production is entirely processed into PDO cheeses (Pecorino Romano, Pecorino Sardo and Fiore Sardo)

**Pyramidal management of the purebred population**

- 25 elite rams
- 60 sampling young rams
- 240,000 heads; 1,000 flocks
- elite rams
- best dams
- 600 young sampling rams
- 3,600,000 heads; 13,000 flocks

**Controlled Natural Mating**

Grouping ewes with a single sire during the reproduction period ("mating group")

- Reproduction period
  - mating group 1
  - Ram1
  - mating group 2
  - Ram2 or group of rams

- Lambs period
  - Lamb1
    - Sire: ram1
    - Dam: ewe1
  - Lamb2
    - Sire: ram2 or unknown
    - Dam: ewe1

- Lag of 14 days

- Realized either with young rams to progeny test or proven adult rams
- Size depends on the sexual aptitude of the ram and the planned lambing period.
AI was introduced in the breeding scheme mainly to increase genetic links between flocks either through AI rams or NM rams born by AI.

Planned matings between elite AI rams and elite dams are realized to generate the new cohort of young rams to introduce in the AI center.

**Artificial Insemination**

- **AI program**
  - 40-day AI season (May-July)
  - 200-250 flocks served by 60 veterinarians of the Technical Support Association

**Ewes synchronization**
- FGA 40 mg (14 days)
- PMSG 500 U.I.

After 55 h from sponge removal
- Cervical AI
  - fresh semen (15°C)
  - 0.25 ml straws with 400 million sperms
  - 5–7 h after the collection (depending on the distance between the AI centre and the flock).

**Aim**

Evaluating the effect of combining controlled natural mating with artificial insemination on the genetic structure of the flock book.
Data were from the database used for the genetic evaluation of 2007 managed by the Italian Association of Sheep Breeders (ASSONAPA).

The considered dataset included 2,960,169 lactation records from 971,992 ewes in 2,905 flocks from 1986 to 2006.

### Flock and population dynamics

**Material and methods**

The following annual parameters were considered:

- number of registered flocks (FN) with at least 5 milk recorded ewes;
- number of new registered flocks (FIN);
- number of flocks coming out of the flock-book (FOUT);
- total female stock (FS);
- total number of lactating ewes (LS).
**Flock and population dynamics**

### Number of flocks
- Increased by **48%** from 1986 to 2006
- Annual turnover: **10-11%** of flocks were substituted by new registered flocks.

### Female stock
- Quadrupled between 1986 to 2006
- Annual increasing rate:
  - 7% 1986-1993
  - 11% 1994-1999
  - 3% 2000-2006
- Presence of ewes which had their first lambing when they are **2 years old**: (9% of lactating ewes and 36% of first lactations)
- Each year appeared **31% of new recorded ewes (LEIN):**
  - 72% of yearlings in already registered flocks
  - 28% of ewes in new registered flocks
- **27% of ewes coming out** of the flock-book (LEOUT):
  - 81% of culled ewes
  - 19% of ewes in flocks coming out of the flock book

<table>
<thead>
<tr>
<th>Production Year</th>
<th>Female Stock</th>
<th>Lactating Ewes (LE)</th>
<th>LE IN</th>
<th>LE OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>67,376</td>
<td>60,544</td>
<td>22,923</td>
<td>16,690</td>
</tr>
<tr>
<td>1987</td>
<td>73,429</td>
<td>67,244</td>
<td>23,286</td>
<td>19,080</td>
</tr>
<tr>
<td>1988</td>
<td>79,955</td>
<td>73,852</td>
<td>25,392</td>
<td>21,005</td>
</tr>
<tr>
<td>1989</td>
<td>86,256</td>
<td>79,202</td>
<td>27,723</td>
<td>23,398</td>
</tr>
<tr>
<td>1990</td>
<td>92,124</td>
<td>84,954</td>
<td>29,483</td>
<td>25,430</td>
</tr>
<tr>
<td>1991</td>
<td>98,001</td>
<td>89,643</td>
<td>31,375</td>
<td>27,784</td>
</tr>
<tr>
<td>1992</td>
<td>100,055</td>
<td>93,193</td>
<td>30,372</td>
<td>27,596</td>
</tr>
<tr>
<td>1993</td>
<td>102,760</td>
<td>93,193</td>
<td>31,164</td>
<td>25,319</td>
</tr>
<tr>
<td>1994</td>
<td>110,325</td>
<td>102,121</td>
<td>32,681</td>
<td>26,612</td>
</tr>
<tr>
<td>1995</td>
<td>123,176</td>
<td>114,254</td>
<td>39,275</td>
<td>31,126</td>
</tr>
<tr>
<td>1996</td>
<td>130,935</td>
<td>120,988</td>
<td>39,829</td>
<td>32,363</td>
</tr>
<tr>
<td>1997</td>
<td>147,271</td>
<td>134,994</td>
<td>49,130</td>
<td>33,895</td>
</tr>
<tr>
<td>1998</td>
<td>173,556</td>
<td>159,434</td>
<td>60,825</td>
<td>41,474</td>
</tr>
<tr>
<td>1999</td>
<td>195,689</td>
<td>181,439</td>
<td>63,694</td>
<td>51,210</td>
</tr>
<tr>
<td>2000</td>
<td>208,648</td>
<td>194,764</td>
<td>64,853</td>
<td>61,729</td>
</tr>
<tr>
<td>2001</td>
<td>206,620</td>
<td>193,678</td>
<td>59,579</td>
<td>60,812</td>
</tr>
<tr>
<td>2002</td>
<td>210,337</td>
<td>196,095</td>
<td>65,781</td>
<td>53,495</td>
</tr>
<tr>
<td>2003</td>
<td>224,235</td>
<td>208,898</td>
<td>67,151</td>
<td>56,526</td>
</tr>
<tr>
<td>2004</td>
<td>241,047</td>
<td>225,458</td>
<td>72,574</td>
<td>66,466</td>
</tr>
<tr>
<td>2005</td>
<td>241,919</td>
<td>225,770</td>
<td>70,180</td>
<td>67,011</td>
</tr>
<tr>
<td>2006</td>
<td>238,021</td>
<td>223,227</td>
<td>62,834</td>
<td>68,473</td>
</tr>
</tbody>
</table>
### Flock and population dynamics

#### Average flock size

- **Up to 1996** the percentage of flocks with less than 100 lactating ewes was more than 50% whereas in the last four years it has been reduced to approximately 25%.

- The percentage of flocks with more than 300 lactating ewes ranged from 1% in 1986 to 19% in 2006.

#### REMARKS

The **female stock** of the selected population is approximately 8% of the whole population.

This percentage is below the optimal threshold indicated by Elsen and Mocquot (1974) for dairy sheep.

Organizational problems in applying selection tools limited the number of registered flocks and the flock size. However, we had a positive evolution of the number and size of registered flocks.
**Flock and population dynamics**

**REMARKS**

The **average flock size** is important to permit an **accurate progeny test** either in terms of **number of daughters per sire** or number of **compared rams within flock**.

Unfortunately, the **increase in number of flocks** has been coupled with a **high rate of coming out flocks**. The **annual turnover** of flocks led to a high percentage of ewes with unknown parents with two main negative effects:
- **limited depth** of the **relationship matrix**
- **lower effective size** of the selected population

Reducing by management techniques the **high percentage of first lambings of 2 years old ewes** is important to increase the **number of rams indexed** on the basis of their **first year mating group** and the **accuracy of the progeny test**

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**Breeding management**

**Material and methods**

The following annual parameters were considered:

- number of replacement ewes (**NR**)
- number of breeding males (**NS**)
- number of mating groups (**NMG**)
Ram classification

Progeny test time frame

<table>
<thead>
<tr>
<th>Sire age</th>
<th>Birth</th>
<th>1st service</th>
<th>Birth of 1st service daughters</th>
<th>2nd service</th>
<th>Lambing of 1st service daughters</th>
<th>3rd service</th>
<th>Genetic evaluation</th>
<th>First use as proven sire</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>18</td>
<td>23</td>
<td>30</td>
<td>39</td>
<td>42</td>
<td>48</td>
<td>54</td>
</tr>
</tbody>
</table>

S1: sampling rams being progeny tested at their first mating year

S2: sampling rams being progeny tested for which the size of previous mating groups was not sufficient to obtain 15 lactating daughters

W: sampling rams being indexed for which the size of previous mating groups was sufficient to obtain 15 lactating daughters

P1: rams at first mating year as proven

P2: rams at successive mating years as proven

Breeding management

Number of Mating Groups

<table>
<thead>
<tr>
<th>Birth year</th>
<th>Sires</th>
<th>NM Sires</th>
<th>MG</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>1,127</td>
<td>1,094</td>
<td>1,165</td>
<td>513</td>
<td>246</td>
<td>161</td>
<td>103</td>
<td>142</td>
</tr>
<tr>
<td>1995-2000</td>
<td>1,592</td>
<td>1,450</td>
<td>1,530</td>
<td>617</td>
<td>319</td>
<td>236</td>
<td>156</td>
<td>202</td>
</tr>
<tr>
<td>2001-2005</td>
<td>1,792</td>
<td>1,643</td>
<td>1,707</td>
<td>709</td>
<td>316</td>
<td>276</td>
<td>193</td>
<td>214</td>
</tr>
</tbody>
</table>

- 1.9 MG per flock;

Percentage of flocks according to the number of mating groups:

- 52% with only 1 MG
- 38% with 2 or 3 MG
- 10% with more than 3 MG
Breeding management

Mating Groups according to the sire classification

<table>
<thead>
<tr>
<th>Birth year</th>
<th>Sire NM</th>
<th>Sire MG</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>1,127</td>
<td>1,094</td>
<td>1,165</td>
<td>513</td>
<td>246</td>
<td>161</td>
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<td>156</td>
</tr>
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<td>1,792</td>
<td>1,643</td>
<td>1,707</td>
<td>709</td>
<td>316</td>
<td>276</td>
<td>193</td>
</tr>
</tbody>
</table>

- 42% of sampling rams being progeny tested at their first mating year (S1)
- 20% of sampling rams being progeny tested for which the size of previous mating groups was not sufficient to obtain 15 lactating daughters (S2)
- 15% of sampling rams being indexed for which the size of previous mating groups was sufficient to obtain 15 lactating daughters (W)
- 10% of rams at first mating year as proven (P1)
- 13% of rams at successive mating years as proven (P2)

A proven sire was used on average for 2.0 ± 1.3 years (ranging from 1 to 12 years)

Breeding management

Sampling rams (PT): length of the progeny test

<table>
<thead>
<tr>
<th>Period</th>
<th>PT</th>
<th>PTF</th>
<th>PTF1</th>
<th>PTF2</th>
<th>PT</th>
<th>PTF</th>
<th>PTF1</th>
<th>PTF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>482</td>
<td>355</td>
<td>192</td>
<td>319</td>
<td>16</td>
<td>14</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>1995-2000</td>
<td>589</td>
<td>448</td>
<td>246</td>
<td>398</td>
<td>48</td>
<td>45</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>2001-2005</td>
<td>691</td>
<td>484</td>
<td>282</td>
<td>450</td>
<td>49</td>
<td>47</td>
<td>32</td>
<td>46</td>
</tr>
</tbody>
</table>

- The age at first mating ranged from 6 months to 11 years (66% was less than 2 years old)
- 73% of natural mating rams concluded the progeny test (PTF)
  - 41% with the first mating year (PTF1)
  - 66% with the first two mating years (PTF2)
- 94% of artificial insemination rams concluded the progeny test (PTF)
  - 68% with the first utilisation year (PTF1)
  - 92% with the first two utilisation years (PTF2)
- Since 2000 the average annual number of newly indexed rams has been 531.
Breeding management

Replacement Ewes: management of the mating groups

<table>
<thead>
<tr>
<th>Birth year</th>
<th>Replacement Ewes</th>
<th>AI</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>P1</th>
<th>P2</th>
<th>NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>25,385</td>
<td>890</td>
<td>8,142</td>
<td>2,751</td>
<td>3,185</td>
<td>1,969</td>
<td>2,683</td>
<td>5,765</td>
</tr>
<tr>
<td>2001-2005</td>
<td>56,889</td>
<td>3,691</td>
<td>12,012</td>
<td>5,285</td>
<td>6,414</td>
<td>4,148</td>
<td>4,652</td>
<td>20,687</td>
</tr>
</tbody>
</table>

- 31% of replacement was from unknown sire (NN)
- 6% of ewes born from unknown sires were in flocks with less than 3 years of milk recording
- 27% of registered flocks had all ewes from unknown sire.

The percentage of ewes without pedigree was high even in the already registered flocks due to the controlled natural mating management

Breeding management

The mating group management and the category of the chosen rams are the most important factors negatively affecting the generation interval and the accuracy of the progeny test.

Possible improvement strategies:

- a first use of ram by 18 months of age and a size of the mating group sufficient to produce at least 15 first lactation daughters of one year age (40 to 50 ewes)
- reducing the number of rams older than 18 months used at first mating.
- applying management techniques able to increase the percentage of ewes with the first lambing at 1 year age.
- limiting the habit of using rams in the lag between the first mating and the indexation
- reducing the length of the reproductive life of a proven ram
Breeding management

Artificial Insemination Program

- AI program started at experimental level in 1986 and it was applied on large scale since 1995.
- The average number of AI breeding males was 41 in 1985-1994, 142 in 1995-2000 and 149 in 2001-2005 (4%, 9% and 8% of the total number of breeding males in the 3 periods respectively).
- The percentage of NM rams born by AI moved from 2% in 1986-1994 to 32% in 2000-2005, connecting 19% of flocks not directly involved in the AI program.

Breeding management

Artificial Insemination Program : remarks

- The decreasing of AI spreading and fertility rates after 2000 was due mainly to the blue-tongue crisis.
- Furthermore, the negative economic conjuncture determined by the decrease of milk price and the increase of production costs led farmers to cut some breeding activities.
- Big efforts are being made to come back to the same AI rate of the end of nineties.
Materials and method

Three CG within a flock year are considered in the genetic evaluation model: yearlings, mature ewes lambing before or after December the 15th.

- The genetic links between contemporary groups were evaluated considering the AI rate and the exchange of NM rams.

- Two levels of NM rams producing genetic links were considered:
  - Rams born in one flock and used in another one (external rams)
  - Rams with daughters in more than one flock.

Genetic connectedness

A database including only records from CG with daughters of at least one sire who had offspring in at least one other CG including daughters of other sires was built.

All CG included in this database were considered connected.

For each CG the number of direct links was calculated as the number of other CG with at least one sire in common.
### Rams producing genetic links

Percentage of **external rams**, i.e. rams born in one flock and used in another one:

<table>
<thead>
<tr>
<th>Period</th>
<th>Total CG</th>
<th>Known Sire CG</th>
<th>Connected CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>79%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995-2000</td>
<td>73%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-2005</td>
<td>62%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentage of **NM rams with daughters in more than one flock**:

<table>
<thead>
<tr>
<th>Period</th>
<th>Total CG</th>
<th>Known Sire CG</th>
<th>Connected CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1994</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995-2000</td>
<td>29%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-2005</td>
<td>23%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Average number of contemporary groups (CG) for each year of genetic evaluation

<table>
<thead>
<tr>
<th>Contemporary Groups (CG)</th>
<th>Period</th>
<th>Total CG</th>
<th>Known Sire CG</th>
<th>Connected CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only Yearlings</td>
<td>1986-1995</td>
<td>5,447</td>
<td>4,843</td>
<td>3,183</td>
</tr>
<tr>
<td></td>
<td>1996-2001</td>
<td>11,856</td>
<td>10,433</td>
<td>7,878</td>
</tr>
<tr>
<td></td>
<td>2002-2006</td>
<td>17,311</td>
<td>14,875</td>
<td>11,754</td>
</tr>
<tr>
<td>All age classes</td>
<td>1986-1995</td>
<td>16,432</td>
<td>13,887</td>
<td>13,207</td>
</tr>
<tr>
<td></td>
<td>1996-2001</td>
<td>37,087</td>
<td>31,361</td>
<td>30,560</td>
</tr>
<tr>
<td></td>
<td>2002-2006</td>
<td>54,431</td>
<td>45,323</td>
<td>44,313</td>
</tr>
</tbody>
</table>

- **68%** of connected yearlings CG
- **81%** of connected all age classes CG
Combining controlled natural mating with artificial insemination allowed to reach a good level of direct genetic connectedness in the selection scheme of Sardinian breed.

The number of completely disconnected flocks had a strong decrease in the last 20 years.

A more precise evaluation of the genetic connectedness of the registered Sardinian breed population is needed to identify the best strategies for combining AI and controlled natural mating.
Artificial insemination is surely the most important breeding tool to permit sound genetic evaluations of dairy sheep breeds.

Al large-scale application encountered strong limitations either in some Western Europe countries or in East Europe and North Africa.

The strategy of combining small rates of Al with controlled natural mating could be effective.

An accurate modelling of the selection scheme is needed to optimise the Al rates and the genetic impact of the controlled natural mating.