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).

Pyramidal management of the purebred population

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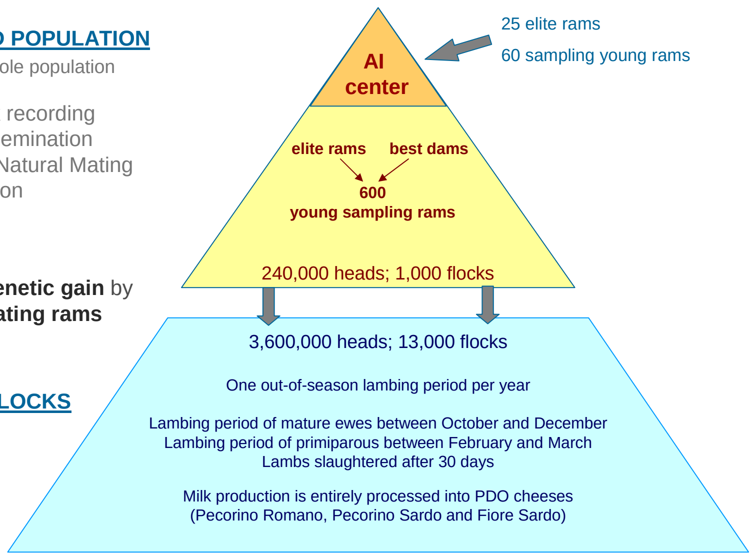
SELECTED POPULATION

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



Controlled Natural Mating

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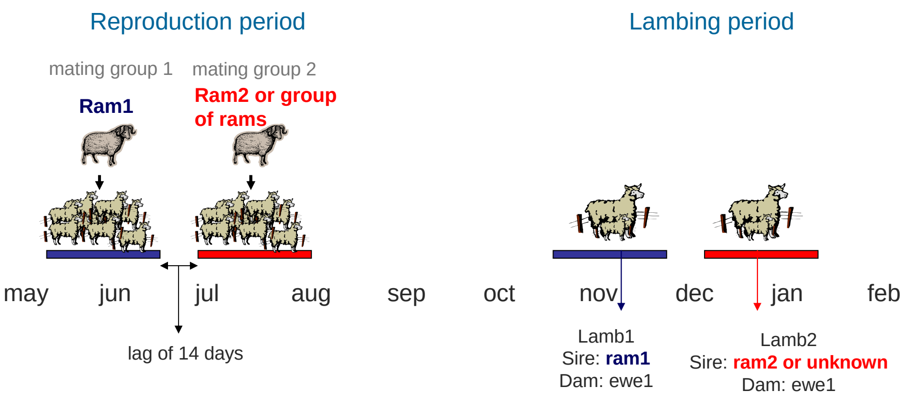
Grouping ewes with a single sire during the reproduction period ("**mating group**")



- 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.

Artificial Insemination

- **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

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.

Available data

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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

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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

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Production Year	Flock Number	Flocks IN	Flocks OUT
1986	777	96	70
1987	803	107	76
1988	834	124	84
1989	874	119	94
1990	899	103	91
1991	911	75	99
1992	887	81	91
1993	877	87	74
1994	890	114	67
1995	937	90	71
1996	956	148	77
1997	1,027	188	78
1998	1,137	148	129
1999	1,156	130	108
2000	1,178	137	133
2001	1,182	142	146
2002	1,178	127	121
2003	1,184	125	151
2004	1,158	110	160
2005	1,108	104	145
2006	1,067	119	106

Number of flocks

- increased of **48%** from 1986 to 2006
- annual turnover: **10-11%** of flocks were substituted by new registered flocks

Flock and population dynamics

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Production Year	Female Stock	Lactating Ewes (LE)	LE IN	LE OUT
1986	67,376	60,544	22,923	16,690
1987	73,429	67,244	23,286	19,080
1988	79,955	73,852	25,392	21,005
1989	86,256	79,202	27,723	23,398
1990	92,124	84,954	29,483	25,430
1991	98,001	89,643	31,375	27,784
1992	100,055	93,194	30,372	27,596
1993	102,760	93,193	31,164	25,319
1994	110,325	102,121	32,681	26,612
1995	123,176	114,254	39,275	31,126
1996	130,935	120,988	39,829	32,363
1997	147,271	134,994	49,130	33,895
1998	173,556	159,434	60,825	41,474
1999	195,680	181,439	63,694	51,210
2000	208,648	194,764	64,853	61,729
2001	206,620	193,678	59,579	60,812
2002	210,337	196,095	65,781	53,495
2003	224,235	208,898	67,151	56,526
2004	241,047	225,458	72,574	66,466
2005	241,919	225,770	70,180	67,011
2006	238,021	223,227	62,834	68,473

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

Flock and population dynamics

Average flock size

Production Year	Flock size (FS)	SD FS	MAX FS
1986	78	59	496
1987	84	63	525
1988	89	71	562
1989	91	72	640
1990	94	80	736
1991	98	82	828
1992	105	86	815
1993	106	84	630
1994	115	93	990
1995	122	104	1,206
1996	127	109	1,294
1997	131	110	1,148
1998	140	117	1,311
1999	157	129	1,447
2000	165	137	1,397
2001	164	142	1,435
2002	166	144	1,537
2003	176	150	1,572
2004	195	162	1,646
2005	204	168	1,489
2006	209	178	2,114

- **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**.

Flock and population dynamics

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**

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

	Birth	1st service	Birth of 1st service daughters	2nd service	Lambing of 1° service daughters	3rd service	Genetic evaluation	First use as proven sire
Sire age	0	18	23	30	39	42	48	54
Daughters age			0	7	15	19	24	30

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

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

- **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

Birth year	Sire	NM Sire	MG	S1	S2	W	P1	P2
1985-1994	1,127	1,094	1,165	513	246	161	103	142
1995-2000	1,592	1,450	1,530	617	319	236	156	202
2001-2005	1,792	1,643	1,707	709	316	276	193	214

- **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):lenght of the progeny test

	NM				AI			
Period	PT	PTF	PTF1	PTF2	PT	PTF	PTF1	PTF2
1985-1994	482	355	192	319	16	14	10	14
1995-2000	589	448	246	398	48	45	35	44
2001-2005	691	484	282	450	49	47	32	46

- 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

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Replacement Ewes : management of the mating groups

Birth year	Replacement Ewes	AI	S1	S2	W	P1	P2	NN
1985-1994	25,385	890	8,142	2,751	3,185	1,969	2,683	5,765
1995-2000	46,562	3,839	10,397	5,299	5,314	3,241	4,177	14,295
2001-2005	56,889	3,691	12,012	5,285	6,414	4,148	4,652	20,687

- **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

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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

Program year	AI Doses	Flock in AI program	AI rate
1986	1,753	62	1.1
1987	2,062	68	1.6
1988	3,610	88	2.7
1989	4,943	108	3.9
1990	8,240	145	5.7
1991	7,304	143	4.9
1992	5,218	181	5.3
1993	8,420	196	8.2
1994	10,895	269	9.2
1995	16,273	349	11.8
1996	17,109	361	11.9
1997	17,468	376	12.7
1998	19,043	384	13.4
1999	20,773	371	14.1
2000	20,519	354	12.4
2001	18,735	309	10.4
2002	19,618	351	11.9
2003	18,594	294	8.5
2004	18,286	290	8.5
2005	15,129	250	10.0
2006	12,778	210	
2007	13,539	201	

Artificial Insemination Program

AI rate: number of ewes from AI sires on the total number of lactating ewes from known sires

- **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 numbreeding 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

Links between contemporary groups

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

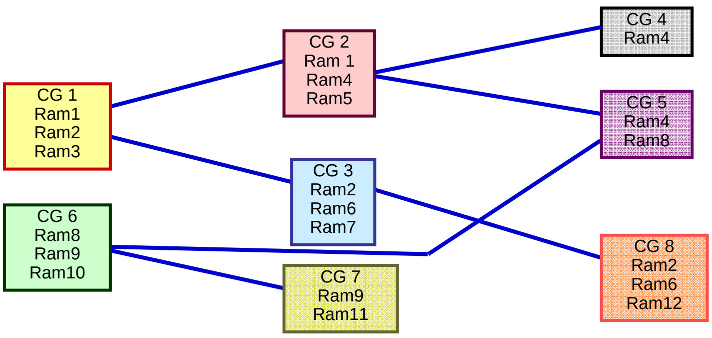
- **Two levels** of NM rams producing **genetic links** were considered:
  - rams born in one flock and used in another one (external rams)
  - rams with daughters in more than one flock.

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.



Links between contemporary groups

Rams producing genetic links

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

- **79%** in 1985-1994
- **73%** in 1995-2000
- **62%** in 2000-2005

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

- **30%** in 1985-1994
- **29%** in 1995-2000
- **23%** in 2000-2005

Links between contemporary groups

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

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

- **68%** of connected yearlings CG
- **81%** of connected all age classes CG

Links between contemporary groups

Percentages of 2007 CG per **number of links (DL)** with other CG

Only Yearlings CG				All age classes CG			
NM		NM+AI		NM		NM+AI	
DL	%	DL	%	DL	%	DL	%
1-3	66.6	1-24	9.3	1-4	13.6	1-99	10.1
4-5	16.9	25-99	29.4	5-9	25.2	100-199	11.2
6-10	14.2	100-200	33.6	10-19	25.0	200-499	26.8
11-20	2.3	200-499	26.2	20-49	28.4	500-999	28.8
> 21	0.0	500	1.4	> 50	7.8	> 1,000	23.0

- **No CG** resulted completely disconnected
- More than **80%** of NM yearlings CG showed from 1 to 5 direct links

Links between contemporary groups

REMARKS

- **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**.

Conclusion

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- **Artificial insemination** is surely the most important breeding tool to permit sound genetic evaluations of dairy sheep breeds.
- **AI 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 AI** with **controlled natural mating** could be effective
- An **accurate modelling** of the selection scheme is needed to optimise the AI rates and the genetic impact of the controlled natural mating