

## GENETICS AND BREEDING OF DAIRY GOATS IN FRANCE

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### Summary

A summary is given on the production conditions of dairy goats in France and the selection program. In France, most of goat milk is used for cheese production and the main objective of the selection program is the improvement of matter yields and matter contents to insure a chemical composition of milk adequate for cheese production. While the genetic variation for milk and contents has been well studied, other complementary traits such as udder traits and milkability are increasingly studied for their eventual inclusion in the selection objective. The implementation of the genetic program is described at three levels: data collection, genetic evaluation and selection scheme. For data collection, validation on animal identification and parentage are routinely done by checking the reproductive dates but also by direct parentage tests on samples using microsatellite polymorphisms. Milk recording, concerning about 270000 goats, is based on A4 and AT4 methods, with an increasing use of microcomputers in the herds. An animal model BLUP procedure has been used since 1993 for the genetic evaluation of dairy traits (milk, fat and protein yields, and protein and fat content) and, since 1999, for type traits. The selection scheme, based on the use of artificial insemination, benefits from the use of the casein polymorphism since 1996.

### Résumé

Les conditions de production des chèvres laitières et le programme de sélection sont résumés. En France, le lait caprin est destiné presque exclusivement à la transformation fromagère et les objectifs prioritaires du schéma de sélection sont l'amélioration des quantités des matières utiles et de la richesse du lait pour assurer une composition chimique du lait adéquate pour la transformation fromagère. Alors que le déterminisme génétique du lait et de ses constituants a été largement étudié, des caractères complémentaires comme la morphologie mammaire et le débit de traite sont étudiés pour leur éventuelle inclusion dans l'objectif de sélection. La mise en oeuvre du programme de sélection est décrite à trois niveaux: acquisition des données, évaluation génétique et schéma de sélection. Des validations sur l'identification des animaux et leurs filiations sont faites en routine par vérification des dates de reproduction et par des tests de filiation utilisant le polymorphisme des microsatellites. Le contrôle laitier, concernant environ 270000 chèvres, bénéficie des méthodes A4 et AT4 et d'une utilisation croissante de la saisie informatisée dans l'élevage. Le modèle animal BLUP est utilisé depuis 1993 pour l'évaluation génétique des caractères laitiers et, depuis 1999, pour l'évaluation de la morphologie. Le schéma de sélection, basé sur l'utilisation de l'IA, bénéficie de l'utilisation du polymorphisme des caséines depuis 1996.

## INTRODUCTION

Applied genetic improvement programs need a careful evaluation of the context of production and the consumer demands, summarized in section 1 for the French dairy goat industry. Knowledge of the genetic variation of economically important traits, reviewed in section 2, is also essential to design the selection program which is presented in section 3.

### *1. The French context*

Dairy goats are mainly concentrated in 4 regions (Poitou-Charentes, Centre, Rhône-Alpes and Midi-Pyrénées) which represent about 80 % of the national goat herd. Farms may have goat production as a exclusive activity or, alternately, combine goat production with other activities such as cereal and beef cattle productions. Many feeding systems are applied, from grazing to complete stabulated feeding, with feedstuff produced directly on the farms or bought. About 30 percent of the farms process their milk into cheese, the rest of the farms sell their production to milk plants.

Table 1 contains figures (rounded) at the national level. The French dairy industry is characterized by the production of labeled high quality cheese (AOC cheeses). At the European level, the French herd represents 11 % of the total number of goats and 29 % of the produced milk (Agreste, 1999). The high productivity of the French herd is due to a marked specialization towards milk production and a good technological level of the farmers. The national dairy goat herd is oriented towards the production of milk to be processed into cheese. The market demands a regular supply along the year of milk with an adequate chemical composition. However, milk production is irregular along the year, with over production in spring and summer and a lack of production in winter months. This irregular milk production along the year is the consequence of the seasonal reproductive rhythm which is specially pronounced for the main French breeds (Alpine et Saanen). Goat sexual activity is not constant : it starts by the end of the summer and it is highest in autumn (Figure 2). Some milk plants transfer excess as frozen curds thus increasing production costs. Moreover, the concentration of kidding dates about February leads to the production of milks, corresponding to middle lactations, with low solid contents in spring and summer. Thus, milk plants incite farmers to breed out of season by applying variable base prices according to the calendar month (figure 1).

### *2. Genetic variability*

#### *2.1. Dairy production*

There are 6 local breeds in France and we try to start up genetic conservation programs for some of them. Here we concentrate on the Alpine and Saanen breeds (Table 2) which are extensively used for commercial milk production and represent the majority of goats under milk recording. Figures in Table 2 correspond to the whole populations under milk recording (registered and nonregistered goats ; all the goats present in the herds are controlled). Protein figures correspond to true protein contents while in other situations nitrogen contents are reported. The Saanen population exhibits a slightly higher milk yield and lower matter contents than the Alpine population but both breeds have similar matter yields (protein and fat yield).

Besides the differences between breeds, there is an important within breed genetic variation (Tables 3 and 4). For both breeds, heritabilities for yields are about 0.35 and heritabilities for contents are higher than 0.50. Matter and milk yields are highly correlated ( $r_g$  over 0.75 ; table 4), protein and fat content are well correlated ( $r_g$  about 0.5) and milk yield and contents are negatively correlated. This general pattern is usually found in other species (cattle, sheep) and indicates that selection is possible for matter yields and contents.

These parameters describe genetic variation under polygenic assumptions. For proteins, studies on biochemical genetics indicated a highly variable  $\alpha s1$ -casein polymorphism, the variants being associated to different rates of synthesis (Grosclaude *et al.*, 1987). The quantitative effects of the goat  $\alpha s1$ -cas on dairy traits were studied by independent on-station (Barbieri *et al.*, 1995) and on-farm experiments (Mahé *et al.*, 1994) indicating that the difference between the extreme genotypes AA (favorable) and FF, in terms of protein content, was 4.5 g/kg, for an overall mean of 29 g/kg and a polygenic standard deviation of 1 g/kg. Also, the favorable allele A outperformed the F allele in protein yield and fat content. Milk from AA genotypes had a higher ratio casein/total protein than FF milk with a corresponding advantage of 15 % in terms of cheese yield (Vassal *et al.*, 1994). Since 1996, this polymorphism is exploited in the selection scheme.

### 2.2. Udder traits and milkability

The existence of a major gene influencing the milk flow rate was suggested by Ricordeau *et al.* (1990) and tested using segregation analysis methods (Le Roy *et al.*, 1995 ; Ilahi *et al.*, 1999). This unknown gene would have two alleles : « hd » (favorable and recessive) and the wild allele denoted by « + ». The difference between the means of hdhd high milk flow and ++ normal goats represents about 3 genetic standard deviations and the residual heritability is moderate (about 0.3). Heritabilities for linear scored udder and teat traits ranged from 0.17 to 0.46 (Table 5), the highest values corresponding to measured traits such as teat length or teat diameter. So, genetic variation exists for these traits but, before including them in the selection objective, more information is needed on the genetic associations between, on one hand, udder traits and milk flow, and, on the other hand, dairy traits, longevity and health indicators such as somatic cell counts.

### 3. Selection program

Selection programs for dairy ruminants benefit from the cooperative action of farmers, milk plants, AI centers and milk recording organizations, with the technical and scientific support of specialized Institutions. In France, this cooperative action has a legal status since 1966 (« loi sur l'élevage » or breeding law). The law specifies the missions of different organizations participating to the selection program ; for dairy goats, 7 organizations are concerned : the EDE (Regional Breeding Bureaux) monitor animal identification ; France Contrôle Laitier is responsible for milk recording and technical advise to farmers, Centres Régionaux Informatiques (CRI) are responsible for the regional data bases and Capri-IA is the artificial insemination center ; Institut de l'Élevage (IE ; Breeding Institute) gives technical support and coordinates data collection, validation and stockage in the national data base ; Institut National de la Recherche Agronomique (INRA) gives scientific support for the definition of objectives, the genetic evaluation and the design of the selection scheme ; Caprigène France gathers representatives of breeders, of cheese producers and of the technical organisations previously described.

### 3.1. Objectives

The objectives of the selection program must be revised periodically in order to adapt genetic goals to market demands and take into account the genetic trends of the populations under selection. Two decades ago, the objective of the French program was the improvement of protein yield (PY) and protein content (PC) with selection thresholds defined for each trait. In 1995, the former independent level selection was replaced by a single selection threshold determined by the index  $I = PY + 0.4 PC$  (Piacère *et al.*, 1997). Selection exclusively on protein was relevant to improve the relative low protein content of the highly productive breeds Alpine and Saanen, in a context where goat milk is marketed almost exclusively as cheese. Selection pressure on protein gave positive trends for protein and also for fat content due to the positive correlation between both traits. However, gains on protein content were higher than those for fat content thus inducing a slight negative trend for the ratio FC/PC. In 1999, the selection index was modified in order to stabilize the FC/PC ratio. The new index is  $I = PY + 0.4 PC + 0.2 FY + 0.1 FC$ .

### 3.2 Data collection

A correct pedigree file is a key point in any selection program. A unique and mandatory identification rule is defined for all goats under milk recording. All pedigrees are validated routinely by comparison of service dates, kidding dates and gestation length. This is completed by a parentage test on 1000 randomly chosen individuals using microsatellites analyses which have efficiently replaced, since 1994, the old analyses based on the polymorphism of blood groups. Parentage tests are also mandatory for all bucks candidates for artificial insemination.

Milk recording concerned 270 000 goats in 1997. The most frequent milk recording method is A4 where goats are controlled monthly at the morning and evening milkings. About 20 % of recorded herds use the AT4 method, where goats are controlled monthly but alternating morning and evening milkings. Milk samples are analyzed (true protein and fat content) with unified procedures at regional laboratories. Analyses of somatic cell counts are also performed in some regions. The use of microcomputers in the herds is increasing with the advantage of making preliminary validations during the test date. INRA automatic jars for milk recording and automatic identification of animals are used in experimental stations.

Type appraisals are collected by Caprigène France by annual visits to member breeders. A linear classification (1 to 9) is used to describe the general appearance and the mammary system. Measurements (cm) are taken for chest perimeter, teat length and teat diameter. Type appraisals are practiced on elite females and daughters of AI bucks.

Since 1995, the  $\alpha s1$ -casein polymorphism is determined routinely for elite females and artificial insemination bucks. Females are genotyped by electrophoretical techniques on milk samples and males are genotyped by PCR-allele specific techniques (Leroux *et al.*, 1993) on blood samples.

The complete information flow is rather complex and it is monitored by the Breeding Institute. Pedigrees, reproductive, milk yield and chemical composition must be sent in a unified format to the Regional Computing Centers (CRI) which apply uniform validation rules. Then, the CRI send files to the national data base located at the CTIG (Computing Center for Genetics) where additional validations are performed. Type appraisal is sent from Caprigène to the CTIG. In 1996, the CTIG replaced the former sequential data base by a relational data base.

### 3.3. Genetic evaluation

Genetic evaluation is carried out by INRA. At present, the genetic evaluation concerns dairy traits and type appraisal. Dairy traits include milk, protein and fat yields and fat and protein content expressed in a total lactation basis. Data are precorrected for a reference lactation length of 250 days. Genetic values are estimated by an univariate animal model BLUP procedure (Boichard *et al.*, 1992) including the fixed effects of region, year, herd, kidding month, lactation number, days dry and genetic groups defined by sex, year of birth and breed. Diffusion of genetic indexes concerns males and females which participate in the selection scheme. Genetic evaluation for type appraisal has started in 1999. Six traits corresponding to general appearance and eleven traits corresponding to the mammary system are analyzed using an animal model BLUP procedure. Data correspond to first classifications of primiparous daughters of AI bucks. The model includes the fixed effects of year, herd, age and lactation stage. Genetic indexes are expressed graphically for AI bucks only.

### 3.4. Selection scheme

The open selection nucleus has 140 000 goats owned by 1000 breeders who are members of Caprigène and benefit from milk recording and AI (60 000 goats inseminated per year). The selection scheme follows the classical pattern for dairy breeds where artificial insemination plays an important role. The use of the  $\alpha s1$ -casein genotype was included in 1996 (figure 3) in order to control mendelian segregation at this locus which determines 50 % of the total genetic variability of protein content. The elite females of the nucleus and the elite AI bucks are selected according to their indexes and their breed standard. Caprigène France organizes then the planned matings between elite parents according to their relationships (to avoid inbreeding) and their casein genotype (to minimize the probability of having progeny homozygous for the unfavorable alleles). This is the first step of AI male selection based on parental data. A second step of AI male selection occurs one year later when the new bucks are born and a within-family selection on casein genotype is practiced in order to avoid putting bucks, handicapped at the casein locus, into progeny test. As shown by Manfredi *et al* (1995), such bucks have very low chances to be kept after progeny testing. The third and final step of AI male selection is the progeny test : about 200 inseminations are made for each young buck in order to insure at least 40 daughters with complete and valid lactations. This important step is finished 3 years later, when the genetic indexes of the new bucks are known and selection of the best 50 % insures the replacement of AI bucks.

### 3.5. Consequences of the selection program

Phenotypic trends for dairy traits in the recorded population are positive for yields and for contents. Phenotypic superiorities of nucleus herds over milk recorded herds estimated by Caprigène are +81 kg, +1 g/kg and +0.6 g/kg for milk yield, fat content and protein content, respectively. These rough superiorities, which may include genetic but also management differences between both populations, are confirmed by Experimental Station data (INRA Station of Bourges; unpublished) indicating that AI daughters outperformed contemporary goats by +89 kg for milk yield and by +1.1 and +0.4 g/kg for fat and protein content, respectively. Genetic and phenotypic trends are dissociated in table 6 and indicate that about 50 % of the phenotypic trends originated from a genetic contribution.

## CONCLUSION

The French dairy goat selection program has entered a mature phase of its development. Challenges for the near future include all the components of the program. For data collection, milk recording should be expanded towards the whole goat population by using simplified milk recording schemes for herds which are, at present, out of the system. For herds under official milk recording, the use of automatic devices would improve the quality of pedigree data (electronic identification) and milk records (automated milk recording). For the selection scheme, a larger use of artificial insemination would allow a better diffusion of the genetic progress in the nucleus towards the general population and the increase of the number of AI bucks put into progeny test. For genetic evaluation, the interest of including the casein information in the genetic indexes should be evaluated and the evolution of the methodological approaches should be insured. But the more challenging problems will come from the diversification of the selection objective by including new traits complementary to dairy production.

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**Table 1. Some figures on the dairy goat industry**

Number of goats	940 000
Number of herds	11 000
Processing cheese (%)	30
Selling production to milk plants (%)	70
Milk production (liters x 10 <sup>6</sup> )	430
Cheese production (kg x 10 <sup>6</sup> )	60
on-farm production (%)	25
milk plants production (%)	75
AOC production (%)	10
Other cheeses (%)	90

Sources : ONILAIT ; Institut de l'Élevage

**Table 2. Milk production of French goat breeds under milk recording (1997)**

	Alpine	Saanen	Crosses
Goats	139 853	120 241	12 692
Lactation length (days)	273	280	266
Milk yield (kg)	760	798	717
Protein yield (kg)	23	23	21
Fat yield (kg)	26	25	24
Protein content (g/kg)	30.7	29.7	29.8
Fat content (g/kg)	34.8	32.4	33.8

Source : Institut de l'Élevage (1998)

**Table 3. Estimates of genetic and phenotypic standard deviations ( $\sigma_p$  and  $\sigma_g$  respectively), heritability ( $h^2$  +/- estimates of standard error s.e., in %), and genetic coefficient of variation ( $CV_g = \sigma_g / av.$ , in %, with av. the phenotypic average of the samples).**

Traits	Alpine breed				Saanen breed			
	$\sigma_p$	$\sigma_g$	$h^2$ +/- s.e.	$CV_g$	$\sigma_p$	$\sigma_g$	$h^2$ +/- s.e.	$CV_g$
Milk kg	133	77.1	34 +/- 1.5	11.8	144	81.6	32 +/- 1.7	12.1
PY kg	3.80	2.28	36 +/- 1.5	11.5	3.96	2.31	34 +/- 1.7	11.5
PC g/kg	2.27	1.72	58 +/- 1.5	5.5	1.94	1.37	50 +/- 1.8	4.7
FY kg	4.99	3.02	37 +/- 1.5	13.2	5.08	3.21	40 +/- 1.8	14.7
FC g/kg	4.04	3.08	58 +/- 1.5	8.8	3.83	2.96	60 +/- 1.8	9.3

Source : Belichon *et al.* (march 1999, unpublished)

**Table 4.** Estimates of phenotypic and genetic correlations (above and below diagonal respectively, +/- estimates of the corresponding standard errors).

**Table 4a.** Alpine breed

	Milk	PY	PC	FY	FC
Milk		+0.933	-0.384	+0.849	-0.159
PY	+0.887 +/- .006		-0.038	+0.884	+0.014
PC	-0.284 +/- .024	+0.186 +/- .027		-0.106	+0.492
FY	+0.765 +/- .012	+0.858 +/- .008	+0.141 +/- .027		+0.377
FC	-0.177 +/- .027	+0.113 +/- .026	+0.614 +/- .016	+0.491 +/- .022	

**Table 4b.** Saanen breed

	Milk	PY	PC	FY	FC
Milk		+0.952	-0.398	+0.855	-0.122
PY	+0.923 +/- .005		-0.111	+0.877	-0.015
PC	-0.288 +/- .032	+0.099 +/- .038		-0.163	+0.410
FY	+0.764 +/- .014	+0.831 +/- .010	+0.079 +/- .036		+0.388
FC	-0.099 +/- .034	+0.102 +/- .032	+0.512 +/- .023	+0.557 +/- .025	

Source : Belichon *et al.* (March 1999, unpublished)

**Table 5.** Estimates of heritability for udder and teat characteristics.

	ALPINE	SAANEN
<b>UDDER</b>		
Fore udder	23	34
Udder profile	34	27
Udder floor	31	28
Medial ligament	33	24
Rear ligament	23	25
<b>TEATS</b>		
length	41	46
diameter	41	40
form	38	34
side profile	21	17
placement	34	30
rear profile	32	32

Source : Manfredi *et al.* (January 1999, unpublished)

**Table 6.** Trends after 10 years of selection for milk yield, protein yield and protein content (250 days lactation)

	Phenotypic (first lactations)	Genetic
Milk yield (kg)	+134	+80
Protein yield (kg)	+5.1	+3.0
Protein content (g/kg)	+2.3	+1.0

Source : Leboeuf *et al.*, 1998

Figure 1. Collected milk and average milk price of goat milk in 1995/1996

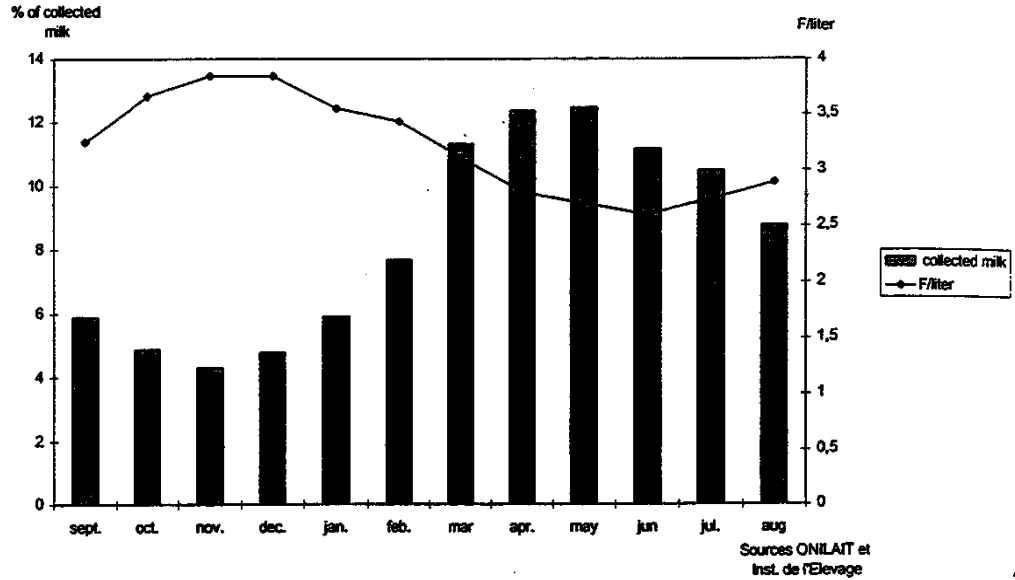
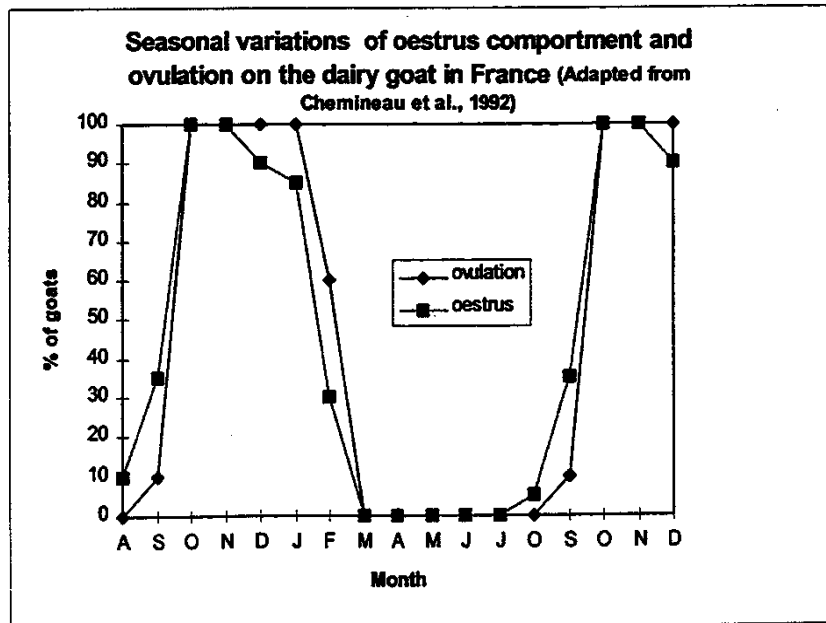
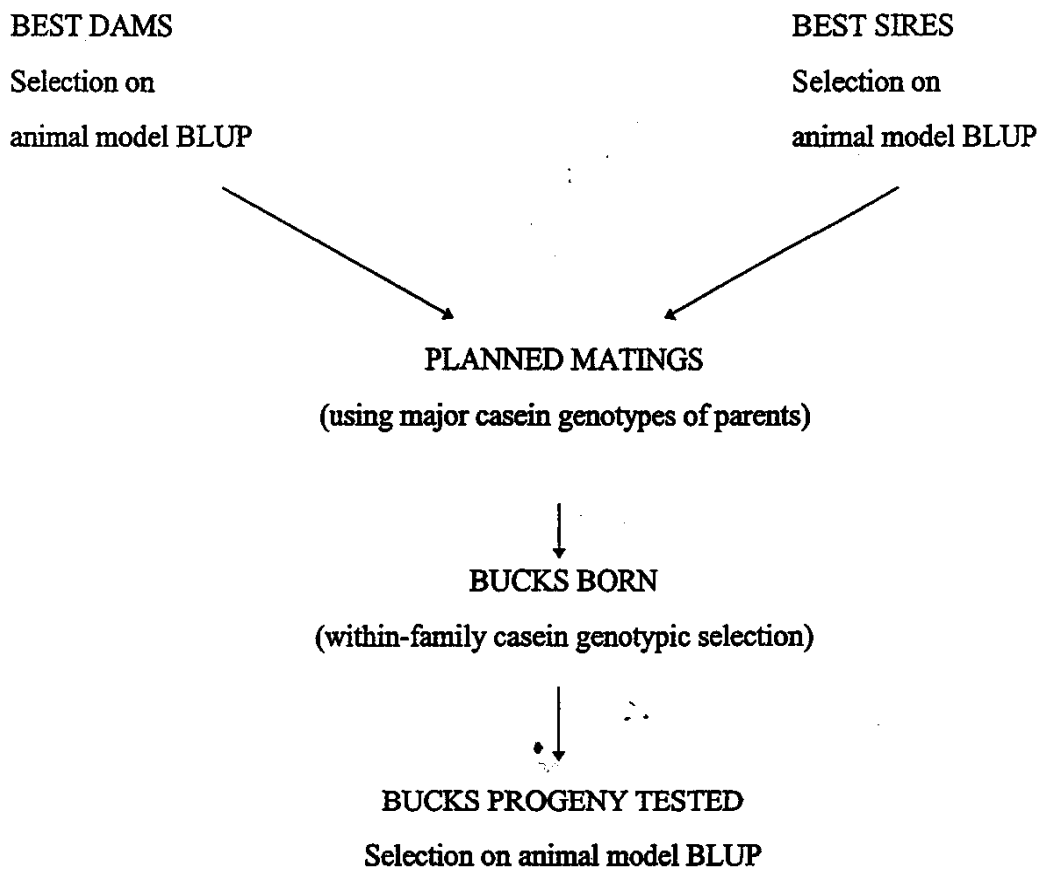


Figure 2: Seasonality of Alpine goats in France



**Figure 3. Selection scheme.**



Source : Manfredi et al. (1998)