# Genetics Of Adaptation Traits For Harsh Environment In Sheep

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## Introduction

Sheep industry is located in both favorable environment (on meadows or associated with grain industry) and in harsh environment. In France sheep industry has decreased in the plains and is now mainly located in harsh environment. Harsh can be wet in marshlands or in meadows (Western France), cold in mountains (Alps, Central Massif, Pyrenees) or dry in southern areas (Causses, Provence or Corsica). Selection strategies for harsh environment could be to select for production traits *in situ* or to identify adaptive traits and select for them together with production traits. Identification of adaptive traits has been a long way research program and consistent results are about to be reached in our topic of sheep breeding.

## Global approach of adaptive traits for harsh environment

**Hardy breeds for harsh environment.** Hardy breeds have been bred for years in harsh environment, they probably have developed many adaptive traits to face to unfavorable conditions (Bouix (1992)). Quite sure they fit the local farming systems and preservation policies of these breeds have been implemented. However selection is needed to improve the efficiency of breeding in such environment.

**Selection for production traits for harsh environment.** Bibé *et al* (1979) made the assumption that production for harsh environment issues from expression of both productive genes and adaptive genes for the breeding environment. Selection in such conditions allow to progress on both groups of traits. The weak point comes from that for changing environment the respective contribution of the two groups of traits is variable. Production traits could be tested in sires breeding centres as a way to monitor the environment but it may be too different of the production environment. Breeding Values Estimations of traits affected by Genetic-Environment Interaction will be biased. On farm animal recording for maternal qualities is the way used by French sheep breed societies and concerns 340 000 ewes representing about 30 meat & hardy breeds. Maternal qualities include reproductive traits (prolificacy, seasonal fertility), milking traits (suckling ability measured by Lamb(s) Average Daily Gain between 10 and 30 days) and lamb survival trait.

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**Pure-bred or Cross-bred**. To estimate Genetic-Environment Interaction an experiment was conducted (Bouix (1992)) on two experimental flocks: La Fage raised outdoors in a dry environment (calcareous plateau of Causse du Larzac) together with the Le Merle flock in Provence. Ewes were local breeds (Lacaune at La Fage and Merinos d'Arles at Le Merle), prolific breed (Romanov in both flocks) and the two F1 crossbreds. Traits due to lambs (survival, growth after 30 days) were affected by environment as traits due to ewes (fertility, prolificacy, lamb growth before 30 days) remained stable (Bouix *et al* (2002)) suggesting to wean lambs quite early. Crossbred ewes got the best maternal results from both adaptive genes (from hardy Romanov origin) and heterosis effect, confirming the advantage of F1 or Mule ewes being more productive than local breed ewes.

## Genetics of adaptive traits for harsh environment

Different adaptive traits have been studied dealing with climatic stress, fleece, disease resistance, reproduction seasonality, behaviour and body condition.

**Climatic stress resistance**. An experiment to test adaptation to summer transhumance (Hocquette *et al* (1992)) by measuring the 4-ewes heat production in breathing rooms facing 3 simulated conditions (windy, rainy & windy, calm) showed less heat production for the local Alpine breeds (especially Mérinos d'Arles and Préalpes) than Ile-de-France. Difference between rainy and windy *vs* windy could be related with the higher cover of the fleece of the Merino. Raised under extensive systems, Awassi ewes showed better adaptation traits (lower thyroxine, rectal temperature and pulse rate levels) than those raised under intensive management systems (Hamadeh *et al* (1997)).

**Fleece.** The survival rate has been related to fleece composition collected on lambs at birth (Allain *et al* (2010)). Hairy birth coat influenced favourably birth survival rate from 3 points to woolly one (93 % *vs* 90 %). Coat surface temperature being 5.1°C lower for the hairy lambs indicated that hairy coat help the lamb to maintain his body temperature and prevent loosing calories in the environment. Heritability of lamb birth coat type was 0.58.

**Reproduction seasonality.** Overcoming the seasonality of reproduction allows the lactation (suckling lambs) while pasturing. Development of sheep with a highly reduced seasonality of breeding has been performed using spring fertility measurements (Notter *et al*(2005). However, response to selection using spring fertility remains limited due to very low levels of heritability (<0.1) and ewe age effects on fertility and response to selection. On Mérinos d'Arles ewes, Hanocq *et al* (1999) reported 28 % with spontaneous ovulatory activity in April and consistent heritability and repeatability estimates (0.37 and 0.20, respectively). Pelletier *et al* (2000) found that ovulatory activity was associated with the polymorphism of the gene that encodes melatonin receptor. Further studies between breeds confirm but within breed Ile de France Hernandez *et al* (2005) did not confirm. This polymorphism could not be used as genetic marker of selection for out-of-season breeding ability in sheep. Further investigations are needed to understand genetic control underlying rhythms of reproduction and to access to QTLs and functional mutations for seasonality in sheep.

**Disease Resistance**. Genetic basis on disease resistance in sheep has been demonstrated for major diseases (Davies *et al*., 2009) such as mastitis (Rupp *et al* (2002)), gastrointestinal parasitism (Woolaston *et al* (1991)) and scrapie (Hunter *et al* (1993)). Selection for improving mastitis resistance based on somatic cell counts (SCC) has been implemented in dairy Lacaune (Rupp *et al* (2003)). Results from a divergent selection experiment gave strong evidence that SCC-based selection leads to decreased intra-mammary infection prevalence, clinical expression and associated mean SCC (Rupp *et al*., (2009)). National Scrapie Plan based on the PrP gene polymorphism has enhanced the level of resistance of the French sheep breeds (Sidani *et al* (2010)). Regarding parasite resistance, Gruner *et al* (2003a) showed the convergence between natural and artificial challenge. Selection of rams based on faecal egg counts (FEC) after challenges is currently being tested in two French schemes, such selection programmes applied to some nucleus schemes already exist in Australia (Eady *et al* (1992)), New Zealand, South Africa & UK. Opportunity of alternative selection is expected with QTL detection designs (Gruner *et al* (2003b)) on backcrossed lambs Black Belly–Romane based on microsatellites (Moreno *et al* (2006)) and SNPs markers (Sallé *et al* (2010)).

**Behaviour.** *Between breeds*. At La Fage flock raised outdoors all along the year and fed on rangelands, Boissy *et al* (2005) tested over five consecutive years Romanov and Lacaune pure breeds, the two F1 crossbreeds and the offspring of ewes from these four genotypes sired with Berrichon rams. 1347 weaned lambs from eight genotypes were individually exposed to three challenging tests involving novelty, human contact and social isolation. Ten synthetic variables were used to express social reactivity (*i.e.*, active *vs*. passive strategy), exploratory activity and reactivity to humans. Berrichon crossbreds were more active (*i.e.*, high bleats, locomotion and attempts to escape) than purebreds and F1. Romanov expressed more passive responses (*i.e.*, low bleats and vigilance postures) than Lacaune and crossbreds. Direct additive genetic effects explained most of the differences while maternal influences or heterosis effects were rarely significant. High bleats got highest heritability ($h^2 = 0.48$).

*Within breed*. Then the ewes of the flock were replaced by Romane (Berrichon x Romanov) ewes following an absorption cross of Romane rams on F1 Lacaune x Romanov ewes. Boissy *et al* (2007) estimated the genetic effects on three crops of 1111 lambs issued from 15 sires. Behavioural traits have been measured in weaned lambs during two standardised tests assessing attractiveness to social partners and to human (arena test and corridor test). The 30 original variables have been synthesised into 8 behavioural traits from PCA. Heritability estimates ranged from 0.04 (social attraction) to 0.41 (high bleats after isolation), avoidance of human estimate being medium with 0.29. Primo-detection of QTL with 72 microsatellites markers on 4 families of 361 lambs led to 7 QTL on 6 chromosomes for 5 traits (Boissy *et al* (2007)). 9 families of 950 lambs have been genotyped with the OvineSNP50 bead chip (Moreno *et al,* 2009), detection of QTL being in progress and following fine mapping of relevant genes. Favorable genetic correlations between the behavioural traits and weak phenotypic correlations with growth and carcass traits were found. Genotype-Environment Interaction has been estimated from outdoors and indoors lambs both issued from same sires, it seemed weak since sires ranged similarly for 6 of the 8 traits.

**Body condition.** A mean for the flock to cope to harsh environment is to mobilize body fat reserves when feed is too scarce to face to maintenance plus production requirements, and also to replenish body fat stores when feed exceeds these requirements. La Fage ewes are monitored by body conditions scores (Russell *et al* (1969) all over the year: at mating in November, at mid gestation in January, at lambing in April, at weaning in July, in September. If needed feed is complemented. Analysis of a large data set of scores and liveweights to estimate genetic effects and research on fine phenotypes of body reserves mobilization-recover are to be implemented.

## Conclusion

Despite a need for additional investigations, hairy birth coat, disease resistances, reactivity to human and social attractiveness could be included in selection programmes in the purpose of improving the adaptation of farm animals to harsh environments. Low G x E for behaviour traits to be confirmed allows selection in better environment.
Existence of genetic effects in most of these adaptive traits proves the existence of genetic variability which can be implemented to create genetic progress. This disproves the current opinion where well adapted animals are the least susceptible animals to environmental changes. What leads to low productive animals without genetic improvement prospects.

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