SOME ASPECTS OF THE GENETIC MANAGEMENT OF SMALL BREEDS
Métodos de gestión genética en las razas de tamaño reducido
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Introduction.

In this paper, we propose some mating rules which avoid high rates of inbreeding in closed populations. We deal with small populations, made up of a few hundreds of females, owned by various breeders and splitted into small flocks. Although the methods could be extended so as to take account of artificial insemination and of selection, our propositions are chiefly relevant to local breeds reared under traditional conditions.

Our approach relies on two observations. Firstly we are interested in the first few generations, that is in a period of about twenty years. Secondly, high levels of inbreeding are not due to the closeness of the population but to matings within flocks. Therefore we have studied various schemes of circular matings between reproduction groups, derived from theoretical systems (WRIGHT, 1921; KIMURA, CROW, 1963; COCKERHAM, 1970), and modified to take account of the demographic structure of the breed. Alternative solutions were then compared by means of the numerical calculation of expected mean inbreeding coefficients in the various flocks and cohorts, and over twenty years. Calculation of the effective population number was useful when dealing with the effects of the demographic parameters, but did not provide any information about the early evolution of inbreeding levels, or about the relative merits of various circulation schemes between reproduction groups (de ROCAMBEAU, CHEVALET, MALAFOSSE, 1979). According to these preliminary theoretical studies, setting up a program aimed at controlling inbreeding in a small population involves the following three complementary aspects: gathering animals into reproduction groups, choosing a circulation scheme of males between the reproduction groups, taking account of the demographic peculiarities of the breed.

Reproduction groups.

A group brings together females from a single farm, and their offspring. Males and females of a given group are thus reared within the same farm; there may be several groups in a farm. The various reproduction groups should have as equal sizes and demographic structures as possible, with at least two males. The number of females in a group must be less or equal to the size of the smallest farm in the breed, but it should be large enough to allow for some mass selection. The number of reproduction groups that are possible to make up in a breed depends on the aims of the breeders. The more they are concerned in preserving the genetic variability, the larger the number of groups should be. The more they are interested in within group selection, the larger the groups should be, and the smaller their number.

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A tentative idea to make up the reproduction groups is to gather animals that are more related with each other than with other ones in the population. Defining families in such a way is possible, using kinship coefficients computed from genealogical data, and various algorithms of aggregation. This was done in several breeds of sheep and goat, but resulted in a partition of the population that did not fit with the partition into farms. Females in a single family were found in several farms, so that their mating with males of another group would need either many natural service males or artificial insemination. On another hand we have shown that the way by which animals are gathered in reproduction groups had hardly any effect on the further evolution of inbreeding. Finally, available genealogical data are often unequal or unreliable.

From a practical point of view, two- or three-generations pedigrees of males should only be considered when defining the reproduction groups. Then in each farm, females are gathered according to their relationships with these males.

Circulation scheme.

A circulation scheme is a rule that states with which group of males the females of the various reproduction groups must be mated, each year. Each group may be represented as a point on a circle, and referred to by a number \( n, n=1, \ldots, g \). (figure 1). The offspring from any mating are affected to the same group as their mother, and are therefore reared up within the same farm. At any reproduction season, the mating scheme is defined by \( g \) numbers, \( d_1, d_2, \ldots, d_g \) ( \( 1 < d_n < g, n = 1, \ldots, g \)) which take every value between 1 and \( g \), and mean that the females of group 1 are mated with males of group \( d_1 \), females of group 2 with males of group \( d_2 \), etc... We must have \( d_n \neq n \), so that group \( n \) is not isolated from the population, for every \( n \).

There are mainly two kinds of schemes: fixed schemes, in which numbers \( d_n \) do not depend on time, and cyclical schemes, in which numbers \( d_n \) are periodic functions of time, so that the successive values \( d_n(1), d_n(2), \ldots, d_n(t), d_n(t+1), \ldots \) take every value between 1 and \( g \), except the value \( n \).

Figure 1 gives an example of a fixed circulation scheme, with \( d_1 = 2, d_2 = 3, \ldots, d_{10} = 11, d_{11} = 1 \) (\( g = 11 \)). In fact, the mating scheme is not entirely defined by the function \( d_n(t) \), because some additional rules concerning the relative ages of mated males and females may be needed to avoid some forms of systematic inbreeding like father-daughter mating.

As a general result, cyclical schemes turn out to be the more efficient ones as long as the first five to ten generations are considered, and provided that the number of reproduction groups is large enough (more than ten). Conversely fixed schemes might be better when the population is splitted into about five large groups, and the theory predicts that they are the best ones in the long run although they may lead to high levels of inbreeding in the first generations (figure 2).
Figure 1: Fixed circulation scheme, with 11 groups of reproduction.

Males and females of group n are represented by $\square$ and $\bigcirc$.

Cyclical schemes have additional practical advantages: they buffer the effects of fluctuations in the demographic parameters, they allow for a rapid circulation of genes in the whole population and thus make uniform the genetic levels of the farms, they make it possible to gather animals into reproduction groups irrespective of their relationships, and make it unnecessary to compute every coefficient of inbreeding and of kinship.

No general rule may be proposed to choose the periodic functions $d_n(t)$, but some trends are worth being brought to light. For any n, the series $d_n(1), d_n(2), \ldots, d_n(t), \ldots$ must take all the values 1 to g, except n, so that males of group n, mate successively females of all other groups. Repetitions of a value, as in: $d_1(t) = 2, 2, 4, 4, 6, 6, \ldots$, yield often good results, when the number of times each value is repeated is adjusted to the generation length of the breed. Finally, the definitive choice of a function needs a numerical simulation, for which a general FORTRAN program has been elaborated (de ROCHAMBEAU, CHEVALET, MALAFOSSE, 1979), (chapter 3).
Figure 2: Evolution of the mean inbreeding coefficient $F$ in a model population of about 600 goats, as function of the number of reproduction groups (5, 11 or 23), and of the kind of circulation scheme ($F$: fixed, $C$: cyclical).

Demographic constraints.

The initial building of the reproduction groups must be based upon a precise analysis of the demographic parameters of the breed, and of their fluctuations. Indeed, the mating schemes cannot be regularly applied if some reproduction group is unable to supply its own renewal. In several experiments, the whole program had to be modified because some groups were going to extinction. The number of females must be large enough to avoid such a risk, and to yield surely the needed number of males.

The number of males that are effectively mated each year is the main point to take into account, and the most important economic load. General rules are: the number of males mated each year should be as large as possible, and not less than two per group; each male should cover the same number of females; the turnover of males should be short, for example they should not be used more than two years in sheep or goat.
This constraint on the number of males is the most difficult to fulfill, for economic reasons, since it needs that many males be reared in excess of the number necessary for a simple renewal of the flocks. Overcoming this difficulty and those linked with the sanitary problems attached to the exchanges of males between farms, needs a strong solidarity between breeders and some form of public aid.

Conclusion.

Our propositions hold for populations reared in a traditional way and reproduced with natural fecundation. Introducing artificial insemination with fresh semen would not modify the main conclusions, but would avoid the sanitary problems raised by the circulation of males between farms, it would also allow for an easier definition of reproduction groups. For example a group might gather animals from different farms, groups of larger sizes might be formed. On the other hand the management of the whole program would be probably more compelling for breeders. Congelation of semen would surely allow for different possibilities.

Selection was not introduced in our reasoning. On the one hand predicting the evolution of genetic variability by means of inbreeding coefficients ignores any selection effect, and would be theoretically incorrect with selection. On the other hand, selection is not possible, but in a population with a flourishing demography. One aim of the methods we propose is to avoid extinction for some local breeds, for which selection is hardly possible during the first generations. The problem may be raised only afterwards, for those breeds saved from disappearance.

SUMMARY

Pure breeds are closed populations which may have a rather small effective size, in which it is necessary to avoid high rate of inbreeding. This paper aims at giving general trends of methods by which this problem can be handled. These methods, whose theoretical basis and technical aspects are presented elsewhere (de ROCHAMBEAU et al, 1979, Bull. Tech. Dept. Genet. Anim., Inst. Nat. Rech. Agron., France, n° 31) take account of the splitting down of breeds into flocks. The main suggestions are the following ones:

1. Define reproduction groups in such a way that they are of equal size and are not splitted into different flocks,

2. Choose such a circulation scheme between groups, as males of a given group mate successively the females of all other groups,

3. Several demographic constraints must be fulfilled : reproduction groups must be large enough to give birth to the necessary males ; the number of reproductive males remains the most important factor ; each male should mate an equal number of females ; males should not be used more than two years.

1. Hacer dentro de cada cría grupos de reproducción que tienen la misma estructura demográfica,

2. Determinar un esquema de intercambio de los machos entre los grupos de reproducción de tal forma que cada grupo de machos sea cruzado sucesivamente con todos los grupos de hembras,

3. Dar atención a algunos parámetros demográficos: el tamaño de los grupos de reproducción debe ser suficiente para producir un número suficiente de machos de reemplazo. El número de machos queda el factor más importante. Cada macho tiene que montar el mismo número de hembra. No se tiene que usar los machos más que dos años.

References.


