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ARTIFICIAL INSEMINATION AND GENETIC LAG OF IMPROVEMENT NUCLEUS TO COMMERCIAL HERD

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ABSTRACT

This paper addresses the problem of the use of artificial insemination in order to pass genetic improvement through the population. The gene flow method was used to describe a pyramidal structure including a three way cross. Selection outside the nucleus has no long-term effect on improvement. Asymptotic rate of response in any tier of one strain is the same, providing all genes derive from the nucleus. Artificial insemination increases the capacity of diffusion of bucks. Consequently, the genetic lag of improvement nucleus to commercial herd decreases slightly. However, companies must built up a significant amount of genetic achievement in the improvement nucleus.

INTRODUCTION

The rabbit breeders of Western Europe use breeding stocks resulting from selection companies (Rochambeau, 1994). These companies have a pyramidal structure. There is an improvement nucleus, one or more tiers of multiplication and a production tier. Three or four strains are crossed. Artificial insemination increases the capacity of diffusion of bucks and the sanitary independence between tiers.
Hill (1974) and Elsen (1980) derived a prediction of response to selection with overlapping generations. This paper addresses the problem of the use of artificial insemination in order to pass genetic improvement through the population. The gene flow methodology was used to describe a pyramidal structure. This scheme looks like the structure used to spread out the INRA experimental rabbit strains (Rochambeau, 1998).

MATERIAL AND METHODS

Method

The population is split up into $\mathbf{n_g}$ age-sex groups. Let **X(t)** the vector of the genetic value of each age-sex groups at time **(t).** Let **P** be the matrix which describe how genes get through groups between **(t)** and **(t+1). P** is an $\mathbf{n_g}$-$\mathbf{n_g}$ matrix. Let **V** be the vector, which describes the genetic improvement made in the groups of the nucleus. Equation **(1)** expresses the relation between **X(t)** and **X(t+1):**

$$\mathbf{X(t) = P * X(t-1) + V} \qquad \mathbf{(1)}$$

Some of the groups of each strain contribute to the production stock. Let $\mathbf{Y_A(t)}$ be the mean genetic value of the contribution of strain A:

$$\mathbf{Y_A(t) = a_A * X_A(t-1)} \qquad \mathbf{(2)}$$

The vector $\mathbf{a_A}$ describes the contribution of the strain A groups to the genetic value of the crossbred doe. Similar equations can be derived for other strains. Hence, simple matrix operations can be used to compute the proportion of genes in animal of one population group at any time, which derives from a group of selected animals at an earlier time. There is a genetic lag in the passage of genes from selected animals to the next generation (Hill, 1974). The genetic lag $\mathbf{l_A}$ has a constant value after a small number of generations, providing all genes derive from the improvement nucleus (Elsen, 1980).

$$Y_A(t) = t\,\Delta G_A - l_A \qquad (3)$$

Where ΔG_A is the genetic progress per unit of time in strain A.

Demographic and genetic hypothesis

Consider two strains A and B. A buck from strain B is mated with a doe from strain A to produce a crossbred doe AB. Thereafter this doe is mated with a buck from a terminal cross strain C in order to produce the commercial meat rabbit. Time unit is equal to 9 months. Strains A and B does produce 2.5 offspring per litter; strain C does produce 2 offspring per litter. There are 4.5 litters per unit of time

With **natural mating**, the sex ratio is equal to one buck for 4 does in the improvement nucleus, one buck for 6 does in the multiplication tier and one buck for 8 does in the production tier. One buck produces 8 semen doses per week and 312 per unit of time. To obtain one litter, 1.2 semen doses are necessary. Therefore the sex ratio with **artificial insemination** is equal to one buck for 58 does. We also consider a **"low efficiency"** artificial insemination strategy. We have only 4 litters per unit of time, one-buck produces 4 semen doses per week and 156 per unit of time. To obtain one litter, 2 semen doses are necessary. Finally the sex ratio is equal to one buck for 19 does. The probability of having one litter is equal to 0.8 for one doe and for one buck. The probability of having one more litter is equal to 0.8 for one doe and for one buck.

Strains A and B are selected to improve litter size. Genetic progress is equal to 0.1 rabbit per litter and per generation (Blasco, 1996). Strain C is selected to improve the individual weight at 70 days. Genetic progress is equal to 40 g per generation (Rochambeau, 1994). Generations are discrete and generation interval is equal to 9 months. There is no genetic relationship between litter size and post weaning growth rate. All strains have the same initial genetic value for the 2 traits.

The trait of interest, W_L is the litter weight at 70 days. Let W_L be:

$$W_L(t) = N_{70}(t) * W_{70}(t) \qquad (4)$$

N_{70} is the litter size at 70 days and W_{70} is the individual weight at the same age.

$$N_{70}(t) = (N_{70}(0) + Y_A(t) + N_{70}(0) + Y_B(t)) * (1 + H_D + H_M)\, V_{ws} / 2 \qquad (5)$$

$N_{70}(0)$ is the litter size at time (0). H_D is the direct heterosis effect and H_M is the maternal heterosis effect. H_D and H_M are equal to 0.05 and 0.10 (Blasco, 1996). Finally, V_{ws} is the viability between weaning and 70 days. Let V_{ws} be equal to 0.9.

$$W_{70}(t) = \tfrac{1}{2} W_{70\,C} + \tfrac{1}{4} (W_{70\,A} + W_{70\,B}) \qquad (6)$$

For strain C, we have:

$$W_{70}(t) = W_{70}(0) + \tfrac{1}{2} Y_C(t) \qquad (7)$$

Let $N_{70}(0) = 6.0$ and $W_{70}(0) = 2000$ g. We obtain for time (t):

$$W_L(t) = [6.21 + 0.5175\,(Y_A(t) + Y_B(t))]\,[\,2000 + 0.5\,Y_C(t)] \qquad (8)$$

Breeding schemes

The **natural mating scheme** for strain A is presented by figure 1. The number of animals in each group and the number of groups are fitted in with production targets. There are 3 bucks groups (1 to 3) and 3 does groups (4 to 6) in the improvement nucleus. Groups 1 and 4 are mated to breed the next generation. The 6 groups are mated to breed the does of the first multiplication tier (10). There are 3 bucks groups (7 to 9) and 3 does groups (10 to 12) in the first multiplication tier. The 6 groups are mated to breed the does of the second multiplication tier (13) and the bucks of the first multiplication tier (7). Matrix $\mathbf{P_A}$, and vectors $\mathbf{X_A}$, $\mathbf{V_A}$ and $\mathbf{a_A}$ are given in table 1. These values are easily derived from the above parameters. Vector $\mathbf{X_A}$ gives the initial genetic values of the various groups. It is the vector of the natural mating scheme after 9 time intervals. Vector $\mathbf{V_A}$ indicates that selection is made on bucks from groups 1 and 7 and on does from group 4. A similar natural mating scheme is used for strain

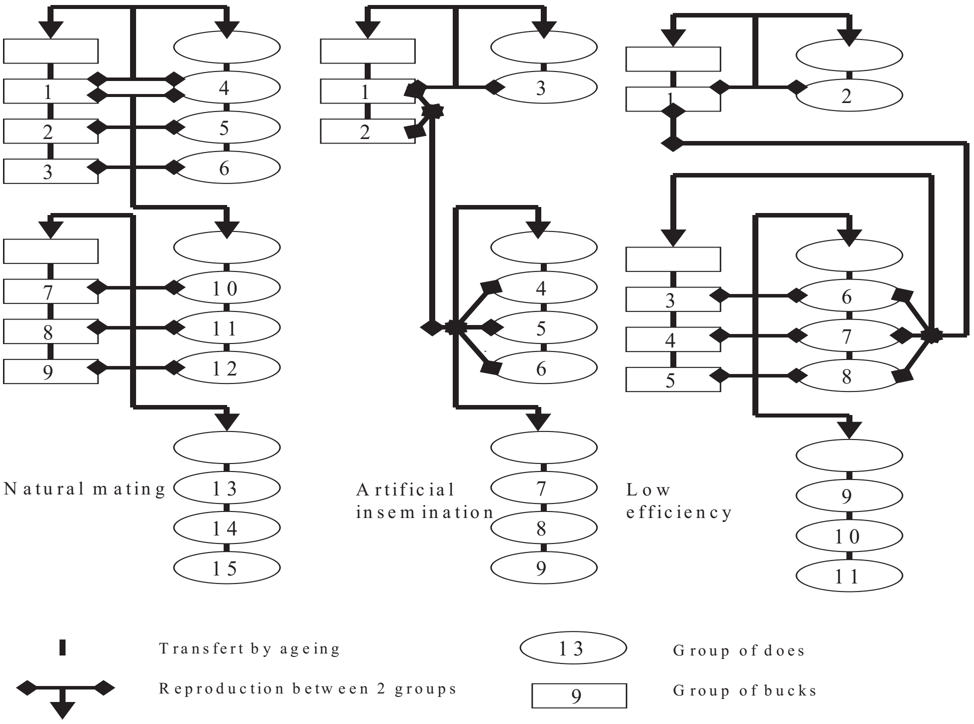

Figure 1 : Three schemes for strain A

Table 1: Elements of $\mathbf{P_A}$, $\mathbf{X_A}$, $\mathbf{V_A}$, and $\mathbf{a_A}$ for the **"Natural mating scheme"**

	Age-sex groups														
P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**0.5**	0	0	**0.5**	0	0	0	0	0	0	0	0	0	0	0
2	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
4	**0.5**	0	0	**0.5**	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	**0.2**	**0.22**	**0.08**	**0.2**	**0.22**	**0.08**	0	0	0
8	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0
10	**0.3**	**0.15**	**0.05**	**0.3**	**0.15**	**0.05**	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0
13	0	0	0	0	0	0	**0.32**	**0.13**	**0.05**	**0.32**	**0.13**	**0.05**	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
X	**0.52**	**0.42**	**0.32**	**0.52**	**0.42**	**0.32**	**0.32**	**0.22**	**0.12**	**0.37**	**0.27**	**0.17**	**0.2**	**0.1**	**0**
V	**0.1**	0	0	**0.1**	0	0	**0.15**	0	0	0	0	0	0	0	0
a	0	0	0	0	0	0	0	0	0	0	0	0	**0.63**	**0.27**	**0.1**

Table 2: Number of age-sex reproduction groups per tier for each scheme

Scheme		Natural mating			Artificial insemination			Low efficiency		
Strain		A	B	C	A	B	C	A	B	C
Improv. Nucleus	Bucks	3	1	3	2	3	1	1	1	1
	Does	3	1	3	1	3	3	1	1	1
1st mult. tier	Bucks	3	3					3	3	3
	Does	3	3		3			3	3	3
2nd mult tier	Bucks		3	3		3			3	
	Does	3		3	3			3		

Table 3: Elements of $\mathbf{P_A}$, $\mathbf{X_A}$, $\mathbf{V_A}$, and $\mathbf{a_A}$ for the **"Artificial insemination scheme"**

	Age-sex groups								
P	1	2	3	4	5	6	7	8	9
1	**0.5**	0	**0.5**	0	0	0	0	0	0
2	**1**	0	0	0	0	0	0	0	0
3	**0.5**	0	**0.5**	0	0	0	0	0	0
4	**0.42**	**0.08**	0	**0.2**	**0.22**	**0.08**	0	0	0
5	0	0	0	**1**	0	0	0	0	0
6	0	0	0	0	**1**	0	0	0	0
7	**0.42**	**0.08**	**0.32**	**0.13**	**0.05**	0	0	0	0
8	0	0	0	0	0	0	**1**	0	0
9	0	0	0	0	0	0	0	**1**	0
X	**0.52**	**0.42**	**0.52**	**0.37**	**0.27**	**0.17**	**0.20**	**0.10**	
V	**0.1**	0	**0.1**	**0.05**	0	0	0	0	0
a	0	0	0	0	0	0	0.63	0.27	0.10

Table 4: Elements of $\mathbf{P_A}$, $\mathbf{X_A}$, $\mathbf{V_A}$, and $\mathbf{a_A}$ for the **"Low efficiency scheme"**

P	1	2	3	4	5	6	7	8	9	10	11
1	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0
2	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0
3	**0.5**		0	0	0	**0.2**	**0.22**	**0.08**	0	0	0
4	0	0	**1**	0	0	0	0	0	0	0	0
5	0	0	0	**1**	0	0	0	0	0	0	0
6	0	0	**0.2**	**0.22**	**0.08**	**0.2**	**0.22**	**0.08**	0	0	0
7	0	0	0	0	0	**1**	0	0	0	0	0
8	0	0	0	0	0	0	**1**	0	0	0	0
9	0	0	**0.32**	**0.13**	**0.05**	**0.32**	**0.13**	**0.05**	0	0	0
10	0	0	0	0	0	0	0	0	**1**	0	0
11	0	0	0	0	0	0	0	0	0	**1**	0
X	**0.52**	**0.52**	**0.32**	**0.22**	**0.12**	**0.37**	**0.27**	**0.17**	**0.2**	**0.1**	0
V	**0.1**	**0.1**	**0.15**	0	0	**0.05**	0	0	0	0	0
a	0	0	0	0	0	0	0	0	**0.63**	**0.27**	**0.1**

B and C. There are 15 groups in strain B, as in strain A (table 2). One multiplication tier is enough to produce the terminal cross bucks. There are 6 groups in the improvement nucleus and 6 in the multiplier tier, i.e. 12 in total.

The **artificial insemination scheme** for strain A is presented by figure 1. Matrix $\mathbf{P_A}$, and vectors $\mathbf{X_A}$, $\mathbf{V_A}$ and $\mathbf{a_A}$ are given in table 3. Artificial insemination increases dramatically the diffusion of genes from one buck. Hence, number of groups could be drastically reduced for strain A (table 2). They are only two groups of bucks in the improvement nucleus. These bucks produce semen for the nucleus and for the first multiplication tier. On the other hand, the promotion of genetic improvement is now made with semen. Consequently, there is only one group of does in the improvement nucleus. Strain B and C are similar (table 2). Six groups in the improvement nucleus and 3 groups of bucks in the multiplication tier are sufficient for strain B. Finally they are 4 groups in the improvement nucleus of strain C. The 3 does groups produce all the terminal bucks for the production herd.

The **"low efficiency scheme"** is alike to the natural mating scheme (figure 1 and table 4). The lower efficiency of reproduction does not allow reducing so drastically the number of groups.

RESULTS AND DISCUSSION

Genetic lag in each strain for each scheme

As quoted previously by Hill (1974) and Elsen (1980), the genetic lag in each strain reaches an asymptotical value after a few time intervals. As a consequence, selection outside the nucleus has no long-term effect on improvement. The asymptotic rate of response in any part on the scheme of one strain is the same, providing all genes in the 2nd multiplication tier derive from the nucleus. Table 5 explores the genetic lag for each strain and each scheme. Artificial insemination scheme induces smaller genetic lags than other scheme. Genetic lags are higher for the low efficiency scheme than for the natural mating scheme. An effective application of artificial insemination is a key issue.

Table 5: Genetic lag in each strain for each scheme

	Genetic lag		
Scheme	l_A (Nb of rabbit)	l_B (Nb of rabbit)	l_C (Grammes)
Natural mating	0.37	0.42	80
Artificial insemination	0.27	0.17	10
Low efficiency	0.52	0.53	98

"Generalised genetic lag" for the trait of interest

From equation (3) and (8), we derive $\mathbf{W^P{}_L(t)}$ for the production tier

$$\mathbf{W^P{}_L(t) = [6.21 + 0.5175\,(t\,\Delta G_A - l_A + t\,\Delta G_B - l_B)]\ [\,2000 + 0.5(t\,\Delta G_C - l_C)]} \qquad \mathbf{(9)}$$

For the youngest groups of the improvement nucleus we derive $\mathbf{W^S{}_P}$ in the same way:

$$\mathbf{W^S{}_P(t) = [6.21 + 0.5175\,(t\,\Delta G_A + t\,\Delta G_B\,)]\ [\,2000 + 0.5t\,\Delta G_C\,]} \qquad \mathbf{(10)}$$

Finally, $\mathbf{l_W = W^S{}_P(t) - W^P{}_L(t)}$ can be defined as a "generalised genetic lag. Thus :

$$\begin{aligned} \mathbf{l_W} &= \mathbf{W^S{}_P(t) - W^P{}_L(t)} \\ \mathbf{l_W} &= \mathbf{0.26\,t\,[l_C\,(\,\Delta G_A + \Delta G_B) + (l_A + l_B)\,\Delta G_C]} \\ &\quad \mathbf{+\,3.105\,l_C + 0.5175\,(\,l_A + l_B\,)(2000 - 0.5\,l_C)} \qquad \mathbf{(11)} \end{aligned}$$

Therefore, $\mathbf{l_W}$ increases as $\mathbf{t}$ increases and does not reach an asymptotical value as the classical genetic lag. As a consequence, the difference between the litter weight at 70 days in the improvement nucleus and in the production tier goes up steadily.

Figure 2 provides a description of the "generalised genetic lag. To determine the initial conditions (tables 2, 4 and 5), we made 9 time intervals with the natural mating scheme. Next, one remains with the "natural mating" parameters. One switches off for "artificial insemination" parameters and the last one for "low efficiency" parameters. The "generalised genetic lag" goes up steadily for the natural mating scheme, as shown by equation **(11)** . It falls down slightly for the artificial insemination scheme, and then rises up slowly. It accelerates steadily for low efficiency scheme. These increases are caused by differences in the genetic lags of each strain (table 5).

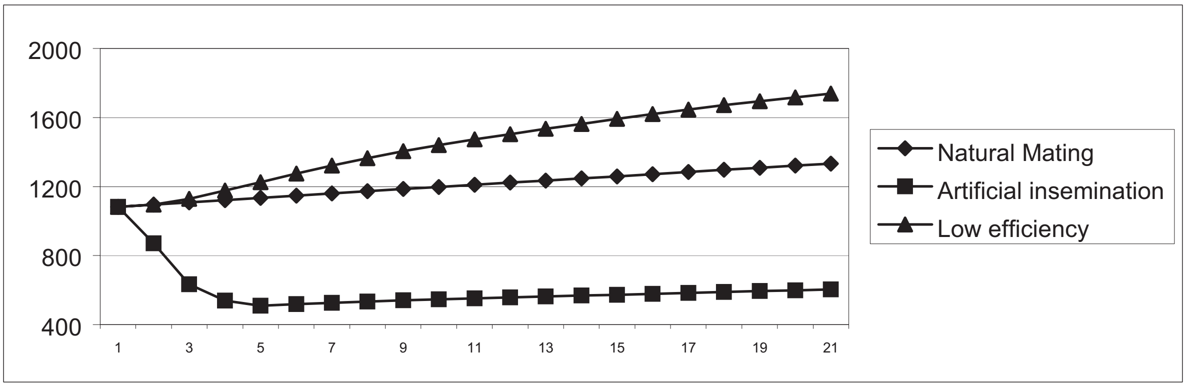

Figure 2: Evolution of the "generalised genetic lag" for the litter weight at 70 days in grams. The initial genetic values are those of the natural mating scheme after 9 time intervals.

Discussion

The model used to describe the 3 schemes relies on various assumptions. The population structure is assumed to remain constant. The population is not very small. Heritabilities and variance do not change. However a slight change in these parameters will not upset results.

During the 70's, pyramid networks for the achievements and promotion of genetic progress were set up in Europe. These schemes produce large batches of homogeneously performing animals. They play an essential role in the rationalisation of rabbit breeding in intensive West European system. These schemes could also present drawbacks. On the first hand, they could be efficient for the spread of sanitary problems. Therefore, it is necessary to check the sanitary condition of the animals produced. On the other hand, do they succeed to fit the animal rate of adaptation with breeders' requirements?

As a **conclusion**, artificial insemination makes it possible to increase the capacity of diffusion of bucks. Consequently the genetic lag of improvement nucleus to commercial herd decreases slightly. Nevertheless, companies must built up a significant amount of genetic achievement in the improvement nucleus. Further work is needed to study if artificial insemination could be used to create more genetic progress in the improvement nucleus.

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