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ANALYSIS OF REPRODUCTIVE PERFORMANCES DURING THE FORMATION OF A RABBIT SYNTHETIC STRAIN

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ABSTRACT

From 1995, a rabbit synthetic strain (called '2666') was formed at INRA for zootechnical purposes by crossing the '2066' strain from INRA and the 'V' strain from the Polytechnical University of Valencia (Spain). The evolution of some reproductive traits and body weight at palpation of the '2666' does was studied from the F1 (first generation cross) to the F4 generation, in comparison with the 'V' does. Furthermore, this evolution was interpreted in terms of Dickerson's crossbreeding parameters. The base strains did not differ significantly for any of the studied traits, either globally or in their direct and maternal genetic value. F1 does exhibited significant individual heterosis for body weight (5.5% of the parental average), pregnancy rate (13.3%), total born (18.3%), born alive (24.4%) and weaned (21.0%) per litter born. Concerning body weight, a significant crossbred superiority over the 'V' line was retained in the F2 but not thereafter. The rate of pregnancy showed no longer crossbred advantage from the F2 on. Concerning litter size traits, the benefit of crossbreeding was maintained until the F4, with however a lower magnitude than in the F1. Body weight and pregnancy rate exhibited maternal heterosis, while litter size did not. Direct epistatic losses were significant for body weight, tended to significance for pregnancy rate but did not affect litter size.

Key words: rabbit, reproduction, synthetic strain, heterosis.

INTRODUCTION

In animal breeding, synthetic populations have been generally formed to combine desirable traits. On the other hand, systematic crossbreeding such as single cross or 3-way crosses are recommended in species with high reproductive rate like pig or rabbit to make maximum use of heterosis and complementarity between breeds or strains(SMITH and KING, 1964; DICKERSON, 1969; ROUVIER, 1981). In this context, the use of a synthetic line as dam line is avoided because of a suspected and theoretically expected loss of heterosis in inter-se matings of F1 or F2 individuals.

It is classically stated that heterosis depends on intra-locus gene interactions i.e. dominance and on inter-loci gene interactions i.e. epistasis (DICKERSON, 1969; HILL, 1982; KINGHORN, 1982). Furthermore, heterosis can affect the individual as well as the maternal component of a trait. Under the simple hypothesis that heterosis only depends on dominance, the extent of expression of heterosis in any crossbred individual, relative to that shown by first-cross individuals (F1), is a linear function of its level of heterozygozity. Under this dominance model and for a trait which is not affected by maternal heterosis, the expectation of heterosis displayed by the F2 cross and the subsequent inter-crossing generations is expected to be half the heterosis of the F1. The experimental evaluations are rather scarce and conflicting (SELLIER, 1982).

The objective of this paper is to evaluate and analyse the evolution of crossbred superiority for reproductive traits, with respect to the 'V' strain, over the first 4 generations of formation of a rabbit synthetic line. This synthetic line, called '2666', was being formed at INRA in Toulouse from 1995 by crossing two strains selected in the context of applied quantitative genetics, a French one and a Spanish one, in order to improve the health state of the French strain (BRUN *et al*, 1998, 1999). Moreover, differences between genetic types involved in these 4 generations will be interpreted in terms of Dickersons's model, in an attempt to estimate individual and maternal heterosis, and epistatic losses, and to explain the evolution of the performances during the process of formation of the synthetics.

MATERIAL AND METHODS

Formation of the synthetic strain

The base strains were the 'V' strain, selected since 1983 on litter size at weaning at the Polytechnical University of Valencia (Spain) (ESTANY *et al*., 1989) and the '2066' strain, selected since 1976 on litter size at birth at INRA in Toulouse (France) (BRUN, 1993). The formation of the synthetics started in may 1995 when 50 pregnant does from the 'V' strain were imported at INRA and their offspring born by hysterectomy (Table 1). The 'V' strain was thus replicated and maintained without selection for 4 further generations in order to monitor the evolution of the synthetics. The strain was structured into 8 paternal lines and its size varied between 40 and 60 does. The first crossbreeding generation between the two strains took place in early 1996 (what we call generation zero or G0), producing the so-called 'F1' crossbreds. The two reciprocal F1 ($F1_V$, from V dams and $F1_6$, from 2066 dams) were identified. F1 dams were evaluated in the presence of both parental strains between July 1996 and May 1997 (G1). We considered as representing the parental strains the breeders present in G1, but not those present in G0. The latter were not comparable, having had different birth conditions: 'V' does were born by caesarean section while '2066' ones were not. Consequently the data of G0 were not considered in the analysis. The 2nd crossbreeding generation between F1 gave rise to the F2. F2 breeders were evaluated between June 1997 and April 1998, in the presence of 'V' breeders which made the connection with the previous generation. The F3 and F4 had the same design. The 'V' line was then cryopreserved.

Table 1. Size of the genetic types during the formation of the synthetic line

Generation	Strain/Cross 'V'	Crossbreds[A]	'2066'	Breeding period
G0	53		55	Oct. 95-May 96
G1	45	47 $F1_V$ / 46 $F1_6$	35	Jul. 96-Jun. 97
G2	36	58 F2		Jun. 97-Apr.98
G3	37	76 F3		May. 98- Apr.99
G4	38	70 F4		Jul. 99-May.00

[A] $F1_V$, $F1_6$ = F1 reciprocal crosses with 'V' and '2066' dam respectively

Breeding method

Reproduction was performed by artificial insemination (10-12 days after littering), with one insemination batch every 3 weeks and picking up of the non fertilised does in the following batch.

Statistical analysis

The traits analysed were does weight at palpation, pregnancy rate (percent of positive palpations), litter traits (total number born, number born alive and number weaned, each one evaluated per litter born).
The traits were analysed using a mixed linear model with the fixed effects of the genetic type of the does (6 levels: 2066, V, F16, F1v, F2, pool of F3 and F4 noted F34), of the physiological status of the does (combination of parity and status of lactation: lactating or not), of the year-season (3 levels at each generation, 12 levels in total) and the random effect of the does. The proc Mixed procedure of SAS was utilised.

Dickerson's parameters (μ, Δd, Δm, Hd, Hm and Rd, explained in the legend of Table 2) were estimated by solving the equation system of Table 2, expressing the genetic types mean values as functions of these parameters. We assume that maternal epistatic losses are negligible Note that F3 and F4, which have the same genetic composition, were pooled and called 'F34'.

Let G be the vector of estimates of the 6 genetic types (2066, V, $F1_6$, $F1_v$, F2, F34) and P the vector of Dickerson's parameters (μ, Δd, Hd, Δm, Hm, Rd).

Let T be the matrix which links G to P (table 2) : G=T*P

The parameters can be calculated as $P=T^{-1}*G = K*G$ where $K=T^{-1}$ and their variance-covariance matrix as : $V_P = K*V_G*K'$

Tables 2. Decomposition of the genetic types means following Dickerson's model

	μ	Δd	Hd	Δm	Hm	Rd
2066	1	1	0	1	0	0
V	1	-1	0	-1	0	0
F16	1	0	1	1	0	0
F1v	1	0	1	-1	0	0
F2	1	0	0.5	0	1	0.5
F34	1	0	0.5	0	0.5	0.5

μ=general mean; $\Delta d=d_6 - d_v$ where d = direct additive genetic effect of a line; $\Delta m=m_6-m_v$ where m = maternal additive genetic effect of a line; Hd= direct heterosis; Hm= maternal heterosis; Rd = direct epistatic losses. F34 is the pool of F3 and F4 types.

RESULTS

Table 3 gives the means of the 6 genetic types, the differences to the V strain and the estimates of Dickerson's parameters.

Table 3. Estimates of genetic types means and of Dickerson's parameters

	Does weight at palpation	Pregnancy rate (%)	Total born	Born alive	Weaned
2066	4090±68	62.4±5.4	8.86±0.46	7.27±0.56	6.19±0.51
V	4191±26	67.7±2.1	8.66±0.17	7.72±0.21	6.73±0.19
$F1_6$	4317±64	71.4±5.1	10.34±0.42	9.40±0.52	7.76±0.48
F1v	4422±62	76.0±5.0	10.37±0.42	9.24±0.51	7.88±0.46
F2	4335±62	69.3±4.8	10.38±0.39	8.78±0.48	7.32±0.43
F34	4176±37	65.6±2.9	9.97±0.24	8.94±0.29	7.52±0.27
2066 - V	-101±72	-5.3±5.6	0.20±0.48	-0.45±0.59	-0.55±0.54
F1 - V	179±58*	6.0±4.6	1.70±0.39*	1.60±0.47*	1.08±0.43*
F2 - V	144±68*	1.6±5.2	1.73±0.42*	1.07±0.52*	0.58±0.47
F34 - V	-15±45	-2.1±3.5	1.31±0.28*	1.22±0.35*	0.79±0.32*
μ	4140±52	65.1±4.1	8.76±0.35	7.50±0.42	6.47±0.39
Δd	3±52	-0.3±4.1	0.12±0.35	-0.31±0.42	-0.22±0.39
Hd	230±50*	8.63±4.0*	1.60±0.33*	1.83±0.41*	1.36±0.37*
Δm	53±50	-2.3±4.0	-0.02±0.33	0.08±0.41	-0.06±0.37
Hm	318±144*	7.4±11.2	0.82±0.92	-0.32±1.13	-0.42±1.02
Rd	-475±193*	-15±15.0	-0.05±1.25	1.39±1.52	1.19±1.38

The base strains and their genetic components (additive direct and maternal effects)

The base strains did not differ significantly for any of the 5 traits studied. However, does from the V strain were heavier at palpation by 101g (2.4% of the base strains average), and tended to be more fertile (8% of the strain average). According to Dickerson's model, the difference between the lines is the sum of line differences in additive direct (Δd) and additive maternal (Δm) effects. Both were not significantly different from zero, whatever the trait considered.

The first generation crosses and their genetic components (direct heterosis and maternal effects)

The first generation crosses (F1) exhibited significant direct heterosis on does body weight (5.5%), on pregnancy rate (13.3%), on total born (18.3%), on born alive (24.4%) and on number weaned (21.0%). Differences between both F1 reciprocal crosses (which means Δm, following Dickerson) were not significant.

The subsequent inter-crossing generations : F2 and pooled F3 and F4 ('F34')

The evolution in the subsequent generations of intercrossing seemed to depend on the trait considered. Concerning body weight at palpation, a significant crossbred superiority over the V line was maintained in the F2 but not after. The rate of pregnancy showed no crossbred advantage over the V line in the F2 and F34. Concerning litter size, the benefit of crossbreeding was maintained until F3 and F4, with however a lower magnitude than in F1.
When these evolutions were interpreted in terms of Dickerson's model, this resulted in the following: Body weight and pregnancy rate exhibited maternal heterosis, with the same magnitude as direct heterosis, although it was not statistically significant for pregnancy rate. This maternal heterosis explain the lower values of F34 does compared to F2 in those traits. Litter size did not show maternal heterosis, particularly number born alive and number weaned. Direct epistatic losses were significant for body weight, hampering the benefits from direct plus maternal heterosis in the F2 and in the F34. Pregnancy rate also showed the same tendencies, although not significantly. Surprisingly, there were no tendencies of epistatic losses for litter sizes, particularly for number born alive and number weaned.

CONCLUSIONS

The evolution of the reproductive performance of the synthetic strain 2666 was estimated during the first 4 generations of its formation, in comparison to the 'V' line performance. This evolution seemed to depend on the trait considered. Does weight at palpation of crossbred 2666 does kept higher than that of 'V' does in F1 and F2 only. Pregnancy rate lost the crossbred superiority observed in F1 while litter size retained the benefit of crossbreeding until the last generation studied.

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