REPRODUCTIVE PERFORMANCE OF A MATERNAL RABBIT CROSS: FAUVE-DE-BOURGOGNE × INRA-1777

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ABSTRACT

Here we compared the reproductive performance of the French rabbit breed Fauve-de-Bourgogne (**Fauve**), the maternal rabbit line INRA-1777 (**INRA**), and their cross (**Crossed**). We followed the life of female rabbits of the three genotypes from 70 days of life until the weaning of litters produced from the third artificial insemination (**AI**) attempt. They had the same age, were house in the same room, were manage under a reproductive rhythm of 42 days and received antibiotic free diets. Crossed females were heavier at first AI than Fauve females (4.2 *vs* 3.9 kg; P<0.05), INRA females being between both genotypes (4.1 kg). Between the first AI attempt and the birth of the first litters, we observed the presence of *Pasteurella spp.* This pathogen impaired the prolificacy of all genotypes and caused mortality of females around parturitions from the second AI attempts. Most losses were from the INRA genotype (four diagnosed deaths for INRA, one for Crossed and none for Fauve females). In brief, the overall losses of Fauve, INRA and Crossed females were two, fourteen and four females, respectively. The high female survival (91%), together with an acceptable reproductive performance (7.5 newborn kits, kit survival during lactation of 80% and weaning weight of kits of 871 g) of Crossed females, indicates that this maternal cross combine the alleged rusticity of the Fauve-de-Bourgogne breed with the reproductive potential of INRA maternal line.

Key words: Genetic resources, crossbreed, local breed, biodiversity, *Oryctolagus cuniculus*.

INTRODUCTION

Genetic selection of purebred rabbit lines tends to erode the genetic diversity. First because most rabbit selection programs used a limited genetic background as the base population (New Zealand White for maternal lines and California for paternal lines), and secondly because selection herds are managed in closed population with no introduction of foreign individuals (Garreau *et al.*, 2015a). The limitation of such strategy is a reduction of the effective population size, the accumulation of inbreeding and a degraded fitness in the selection herds (Pekkala *et al*., 2014).

Intensive farming systems assembles particular conditions - like high stock-densities and frequently use of antibiotics - favouring the dissemination and resistance of pathogens (Pulkkinen *et al.*, 2010). According to Hamilton *et al.* (1990), to resist numerous pathogens, hosts species needs to preserve an array of genotypes, and one strategy to boost the genetic diversity is to cross inbreed-divergent genotypes together. For the rabbit, crossbreds are already present in every commercial farm, being the product of crossing two maternal lines mainly selected for prolificacy (Garreau *et al.*, 2015a). However, as the inclusion of functional trait and the establishment of robust lines is recent in the history of rabbit selection (Sánchez *et al.* 2008; Blasco *et al.*, 2017), it could be argued that the available purebred lines are genetically close and too similar to produce a 'true' outbred individual joining functional and productive traits.

In this sense, the cross between genotypes with different origin and selection history may boost the genetic diversity of rabbit populations. One possibility is to cross high selected lines with local breeds that have been kept and selected for different purposes. The Fauve-de-Bourgogne is a medium size breed, historically used as a backyard animal for meat, now kept and selected for beauty contests by amateur farmers. Fauve-de-Bourgogne farmers report few losses and characterizes this breed as being rustic. The reproductive potential of this breed is very low (fertility rate below 50% and 4.5 newborn kits), but the average daily gain (31.2 g/day) and the survival of growing kits (83%) in an antibiotic 'free' environment are acceptable (Savietto *et al*., 2020). The alleged rusticity of Fauve-de-Bourgogne animals (farmer's observations), and the acceptable growth rate and survival of growing kits make this local breed a potential candidate to be cross with high prolific lines to produce outbred maternal females joining functional and productive traits.

Here we evaluate the reproductive performances and the survival of a maternal rabbit cross between Fauve-de-Bourgogne males and the INRA-1777 line compared to the purebreds giving origin to this cross.

MATERIALS AND METHODS

The French Committee no. 115 for Ethics, Science and Animal Health approved all procedures.

Purebreds and Crossbred Animals

Fauve-de-Bourgogne (hereinafter called **Fauve**) female rabbits (n = 23) were daughters of 9 males and 13 females gathered from five different farms located in the French regions of Alsace, Lorraine and Bourgogne. Fourteen Fauve female rabbits were born on January 2019 and 9 on March 2019. INRA-1777 (called **INRA**) female rabbits (n = 48) were all born on March 2019 from 15 males and 32 females rabbits of the generation 53 of selection for prolificacy. The crossbred Fauve × INRA female rabbits (called **Crossed**; n = 43) were all born on March 2019 from the natural matting of six Fauve male and eight INRA female rabbits.

Housing, Diets and Reproductive Rhythm

Each female rabbits lived indoors in wire cages (W×H×L: 46×60×90 cm) equipped with a plastic mattress, a drinker a food dispenser and a non-treated pine-tree stick (W×H×L: 3×3×10 cm), replaced when needed and used for environmental enrichment purpose. Daylight was set to 16/8h light/dark. The indoor temperature could vary between 15 and 28 °C. All females received from weaning (35 days) to 126 days old a commercial diet for growing rabbits containing 11.3 MJ of DE per kg of DM and 15.4% of CP on a DM basis. From 126 old onwards they received an experimental diet containing 12.4 MJ per kg of DM and 17.0% of CP on a DM basis. The 14 Fauve female rabbits born on January 2019 received the commercial diet for growing rabbits from 70 up to 168 days old and then the experimental maternal diet onwards. Diets contained no antibiotics. Females were first artificially inseminated (**AI**) at age 145 days (14 older Fauve female rabbits 42 days later), being re-inseminated 11 days post-partum date (reproductive cycle of 42 days). Fauve and Crossed female rabbits were AI with fresh semen of Fauve males and INRA females with fresh semen of INRA males. The day after birth and for each AI attempt, females producing milk (visually checked) adopted the alive kits to a number close to the average number of newborn kits of each genotype. We performed cross fostering among genotypes on half of the litters from INRA and Crossed female rabbits. Fauve kits were in all cases adopted by Fauve female rabbits.

Measurements

We weighted females at 1st AI insemination, checked their fertility rate at each AI attempt and assessed their survival rate between 1st and 3rd AI attempt. At each parturition date, we counted the number of newborn and stillbirth kits and weighted the newborn kits. We counted and weighted the alive kits just before and after cross fostering (the day after birth), at 18 days after birth and at weaning. We then calculated the survival during lactation based on the number of nursed kits.

Statistical Analysis

We used the R-software, version 3.6.0 (R core Team, 2019) to analyse our data. We used a logistic regression model to analyse binomial data (fertility rate, female rabbit survival at 3rd AI and kits survival during lactation) and a linear model to analyse continuous data (female live weight at 1st AI, the number and weight of litters and kits). All models included the genotype, the AI attempt and their interaction as dependent variables, except for female live weight at 1st AI and survival between 1st and 3rd AI. For these two variables, only genotype entered the statistical model as a dependent variable. Model for live weight at 1st AI also included age as a co-variable to take into account the age differences of Fauve females.

RESULTS AND DISCUSSION

The population size decreased with time. At 1st AI attempt Fauve, INRA and Crossed females were 23, 48 and 43. At 2nd AI attempt, the figures were 21, 45 and 42 animals, and at 3rd AI attempt Fauve were 21, INRA 34 and Crossed females 39. Female survival was 20 points of percentage higher for Crossed (*P*=0.061) respect to INRA females (Table 1). Most losses occurred around second parturition, when we found four INRA and one Crossed individuals death. The necropsy revealed the presence of *Pasteurella spp* resistant to streptomycin and amoxicillin

Table 1: Survival at third parturition and main reproductive traits of Fauve, INRA and Crossed (Fauve × INRA) females at/from the first, second and third artificial insemination (AI) attempts. Means (SE).

Traits	Genotypes*		
	Fauve	INRA	Crossed
Female survival at 3d AI (%)	91.3 (5.9)	70.8 (6.6)	90.7 (4.4)
Fertility rate at (%)			
First AI attempt	43.5[a] (10.3)	79.2[b] (5.9)	65.1[ab] (7.3)
Second AI attempt	61.9 (10.6)	60.0 (7.3)	71.4 (7.0)
Third AI attempt	23.8[a] (9.3)	61.8[b] (8.3)	69.2[b] (7.4)
Overall	42.2[a] (6.5)	67.7[b] (4.3)	68.6[b] (4.2)
Newborn kits from (n)			
First AI attempt	2.6[a] (1.2)	6.3[b] (0.6)	6.0[b] (0.7)
Second AI attempt	5.3[a] (1.0)	9.6[b] (0.7)	8.2[ab] (0.7)
Third AI attempt	6.3[a] (1.6)	10.7[b] (0.8)	7.3[a] (0.7)
Overall	4.7[a] (0.8)	8.8[c] (0.4)	7.2[b] (0.4)
Weaned kits from (n)			
First AI attempt	3.7 (1.2)	5.1 (0.4)	5.1 (0.4)
Second AI attempt	4.6[a] (1.2)	8.4[b] (0.5)	7.1[b] (0.5)
Third AI attempt	4.3[a] (1.2)	7.9[b] (0.6)	5.6[ab] (0.5)
Overall	4.2[a] (0.6)	7.1[c] (0.3)	5.9[b] (0.3)
Kits survival 0 to 35 days (%)			
First AI attempt	71.4 (9.9)	81.7 (2.6)	85.5 (2.7)
Second AI attempt	73.0 (6.6)	72.7 (2.8)	79.3 (2.6)
Third AI attempt	68.0 (9.3)	70.6 (3.2)	73.2 (3.3)
Overall	70.9 (4.9)	75.4 (1.7)	79.8 (1.7)
Weight of newborn kits from (g)			
First AI attempt	60.9 (3.6)	69.8 (2.2)	63.7 (2.1)
Second AI attempt	52.3[a] (3.1)	63.1[b] (2.2)	58.5[ab] (2.1)
Third AI attempt	49.0[a] (4.9)	63.0[b] (2.4)	62.4[b] (2.1)
Overall	54.1[a] (2.3)	65.3[b] (1.2)	61.5[b] (1.2)
Weight of kits at 18 days from (g)			
First AI attempt	262.7[a] (23.2)	354.4[c] (7.6)	322.8[b] (8.8)
Second AI attempt	279.9[ab] (15.4)	280.6[a] (10.4)	319.8[b] (9.1)
Third AI attempt	246.5[a] (26.7)	280.6[a] (11.2)	362.5[b] (9.7)
Overall	263.1[a] (12.9)	310.9[b] (5.7)	335.0[c] (5.3)
Weight of weaned kits from (n)			
First AI attempt	692.5[a] (40.5)	1039.5[c] (13.6)	872.6[b] (14.3)
Second AI attempt	738.1[a] (31.2)	843.4[b] (14.3)	796.0[ab] (13.4)
Third AI attempt	634.4[a] (47.3)	913.1[b] (15.5)	943.1[b] (14.8)
Overall	688.3[a] (28.3)	932.0[b] (11.0)	870.6[c] (10.9)

[abc] Means of a trait at a given AI attempt followed by distinct letters differs at *P*<0.05. *Fauve: Fauve-de-Bourgogne; INRA: the INRA-1777 maternal line; Crossed: Crossbreed between Fauve-de-Bourgogne males and INRA-1777 females

Losses of the INRA female rabbits between the 2nd and the 3rd AI attempt, involved two additional deaths for no specific reason and the culling of four animals (three with a poor general state and one with an internal abscess). Losses of the Crossed females involved two deaths. The low prolificacy of all genotypes at parturitions of the 1st AI attempt indicates the presence of *Pasteurella spp* between the 1st AI attempt and the 1st parturition. Although it is difficult to precise the number of infected animals that actually tolerated/resisted this pathogen, Crossed females seem to better respond to the *Pasteurella spp* than INRA females, an heritage of its Fauve ancestors and the heterotic effect (survival rate in the same conditions of 91.3%).

Main reproductive traits are in Table 1. At 1st AI attempt, Fauve were lighter than INRA and Crossed females (3877[a], 4108[ab] and 4209[b] g; *P*<0.05). Fertility of Fauve females at 1st and at 3rd AI attempts was low respect to INRA and Crossed females. The overall figures for Fauve, INRA and Crossed females were 42, 68 and 69%, respectively. Fauve females also produced a reduced number of newborn kits than INRA and Crossed. At 1st, 2nd and 3rd AI attempts Fauve produced 2.6, 5.3, and 6.3 newborn kits while INRA produced 6.3, 9.6 and 10.7 kits, resulting in and overall result of 4.7 and 8.8 kits for Fauve and INRA females.

Crossed females produced 6.0, 8.2 and 7.3 newborn kits at 1st, 2nd and 3rd AI attempts, with an overall result of 7.2 kits, a value between Fauve and INRA females. Results for Fauve are in line to that reported by Bolet *et al.* (2004). For the INRA line the results are below those of the first 12 generations of selection (10.4 newborn kits; Garreau *et al.*, 2015b), but are close to the values observed recently at our selection nucleus (on average of 8.4 newborn kits from 5968 litters produced between January 1st, 2015 and January 1st, 2020).

Number of weaned kits is a variable directly related to the number of kits raised after cross fostering, an input linked to our cross fostering practice, and the maternal ability of females affecting kits survival. On average (all cross fostering from AI attempts 1 to 3), Fauve, INRA and Crossed females raised litter of 5.7, 9.2 and 7.3 kits, having a kit survival during lactation of 71, 76 and 80%. As a result, Fauve, INRA and Crossed females weaned 4.2, 7.1 and 5.9 kits in the whole period. The low relative maternal ability of Fauve females (weight of Fauve kits at 18 days was 15% inferior respect to INRA kits) may explain the high nest mortality of Fauve litters compared to the other genotypes.

Live weight of kits at birth, mid-lactation (18 days) and at weaning (35 days) reflects the female capacity to transfer the obtained resources to its progeny. Except for kits from the litters of the 1st AI attempt (no differences between genotypes), Fauve females gave birth to lighter kits (54.1 g on average) than INRA and Crossed females (65.3 and 61.5 g, respectively). At mid-lactation, Crossed kits were heavier than INRA and Fauve kits (335, 311 and 263g, respectively; $P<0.05$), except for kits from the 1st AI attempt (INRA kits were the heaviest ones: 355 g on average; $P<0.05$).

INRA kits from the 1st AI attempt were heavier than both Fauve and Crossed kits (1040, 873 and 693 g, respectively; $P<0.05$). The trend changed in litters produced from the 2nd and the 3rd AI attempt. INRA and Crossed kits had a similar weaning weight, while Fauve kits were always lighter.

CONCLUSIONS

The maternal cross between Fauve-de-Bourgogne males and INRA-1777 females has a litter size of 1.6 newborn kits less than the current generation of the INRA-1777 line. They have, however, a similar fertility rate and kit survival during lactation. Crossed females appear to resist/tolerate better the presence of *Pasteurella spp*, having an adult survival rates at 3rd AI attempt 20 points of percentage higher than females of the INRA-1777 line. This genotype appear to combine the benefits of both ancestors, the alleged rusticity of Fauve-de-Bourgogne breed and the reproductive performance of INRA-1777 maternal line.

ACKNOWLEDGEMENTS

Authors acknowledges the Department PHASE of INRAE institute for the economic support.

REFERENCES

Blasco A., Martínez-Álvaro M., García M.L., Ibáñez-Escriche N., Argente M.J. 2017. Selection for environmental variance of litter size in rabbits. *Genetics Selection Evolution, 49 (1): 48.*

Bolet G., Brun J.M., Lechevestrier S., Lopez M., Boucher S., 2004. Evaluation of the reproductive performance of eight rabbit breeds on experimental farms. *Animal Research 53, 59-65.*

Garreau H., Fournier E., Allain D., Gunia M., 2015a. Génétique et sélection. *In: Gidenne T. (Ed). Le lapin. De la biologie à l'élevage. Editions Quae, Versailles, France, 227-252*.

Garreau H., Balmisse E., Ruesche J., Hurtaud J., Maupin M., Canario L., David I. 2015b. Relation entre les critères de sélection de la lignée INRA 1777 et la survie des lapereaux. *In Proc. 16 Journées de la Recherche Cunicole, 2018 November, Le Mans, France, 77-80.*

Hamilton W.D., Axelrod R., Tanese R., 1990. Sexual reproduction as an adaptation to resist parasites (a review). *PNAS, 87(9), 3566-3573.*

Pekkala N., Knott K.E., Kotiaho J.S., Nissinen K., Puurtinen M., 2014. The effect of inbreeding rate on fitness, inbreeding depression and heterosis over a range of inbreeding coefficients. *Evolutionary applications, 7(9), 1107-1119.*

Pulkkinen K., Suomalainen L.-R., Read A. F., Ebert D., Rintamäki P., Valtonen E. T. 2010. Intensive fish farming and the evolution of pathogen virulence: the case of columnaris disease in Finland. *Proc. R. Soc. B, 277, 596-600.*

R Core Team 2019. R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria. URL: http://r-project.org*

Sánchez J.P., Theilgaard P., Mínguez C., Baselga M. 2008. Constitution and evaluation of a long-lived productive rabbit line. *Journal of Animal Science, 86 (3), 515-525.*