EFFECTS OF DAYLENGTH, AGE AT MATING AND REPRODUCTION WAY ON REPRODUCTIVE PERFORMANCES OF FRENCH ANGORA RABBITS.*

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Abstract - Reproductive performances of 158 French Angora rabbit does were analyzed. They were born in increasing or decreasing daylength and mated in increasing or decreasing daylength, either in natural mating or artificial insemination. First mating occurred early (after the 2nd fleece harvest, and then after the 4th, 6th, 8th), or late (only after the 6th and the 8th fleece harvest). The high acceptance rate, 87%, was influenced only by daylength, in favour of increasing daylength. From 100 mated does, 84 ovulated at least one ovocyte, 53 were pregnant and only 27 had at least one young born alive. Average litter size was 5.3 youngs born, whereas there were 9.5 ova shed and 8.3 implanted embryos (12th day of pregnancy), counted by endoscopy. There were no strong significant differences between the group of does first mated early and those first mated late. However, results of the first parity of does mated early were significantly lower than all the others. Naturally mated does had a significantly lower frequency of ovulation (81.1 *vs* 94.6%, P<0.01), but in ovulating females, artificial insemination led to decrease the implantation rate (64.4 *vs* 73.2%, P<0.01), the litter size at implantation (7.7 *vs* 9.1, P<0.01) and at birth (3.8 *vs* 5.6 live pups, P<0.01). There were no significant correlations between fleece weight and reproductive traits. None of the studied factors had a major influence on the high abortion rate. Artificial insemination did not improve the performances. Further studies on the effect of Angora gene on reproduction are needed.

INTRODUCTION

Angora rabbits are usually raised for production of wool, a fine keratinic fibre production. Selection programs, in France, aim to increase the weight of the fleece in a specific quality, without taking into account reproductive performances. Replacement rate is quite low. Selected does are mated very late, after the 5th or the 6th fleece harvest, to produce the next generation. In some forty years, fleece weight increased from 0.5 to 1.2 kg per adult and year (ROUGEOT and THEBAULT, 1989). Meanwhile, reproduction difficulties were noticed, concerning fertility of males and females, and prolificacy ; in particular, a high rate of abortion during the second half of gestation was suspected by breeders. These poor performances could be due to some antogonism between reproduction and fleece production or to unusually late age at reproduction. A first study (THEAU-CLEMENT *et al.*, 1991) gave some informations about ovulation abilities of the doe and sperm output of the buck. In the present experiment, we study the influence of several non genetic factors, such as fleece production, birth season of the doe, mating season, age at first mating, reproduction way.

MATERIAL AND METHODS

Animals

This experiment was performed in the INRA experimental herd (Le Magneraud). Rabbits were raised individually, in cement hutches with straw litter, under natural daylight. Wool was harvested by defleecing, using a natural depilatory product (Lagodendron © Proval SA, Paris). A total of 158 French Angora rabbit does, born between January 1990 and December 1992, were mated or inseminated between July 1990 and December 1994, using a total of 79 bucks. The females were born in 6 cohorts of approximately 25 does, separated by 7 months, each one proceeding from first parities of the previous cohort. So, there were two periods of birth (3 cohorts in increasing daylength, from January to may, and 3 in decreasing daylength, from August to December). In each cohort, does were randomly separated in two groups : the group "early mating" was first mated one week after the second fleece harvest (at about 150 days) and then after the 4th, 6th and 8th fleece harvest, i.e. every 6 months ; the group "late mating" was first mated after the 6th harvest (at about 550 days), and after the 8th, 6 months later. There were 9 periods of mating, 4 in increasing daylength, from January to June, and 5 in decreasing daylength, from July to December. Half of the females were naturally mated. The others were artificially inseminated with fresh semen 1:5 diluted with Dilap2000 medium (IMV), and injected with 0.2 ml of Receptal (DISTRIVET) in order to induce ovulation. Naturally mated females were systematically presented to the same male once more two days later. Two weeks after mating, they were

* The authors dedicate this paper to Gabriel BLANIE, technician of the experimental herd, who recently died.

examined by laparoscopy using the technique described by SANTACREU *et al.*, (1990). Corpora lutea were counted on each ovary, to estimate the number of ova shed, implanted embryos were counted in each uterine horn. A total of 363 presentations of does for mating or artificial insemination was performed.

Traits analyzed

In the text and in the tables, "mating" refers both to natural mating and artificial insemination. "Pregnant" females are those which had at least one embryo implanted (observed by endoscopy).

The following frequencies were analyzed :

- Acceptance of mating at the first presentation (only for natural mating),
- Occurrence of ovulation in mated does,
- Occurrence of implantation in mated does and in ovulating ones,
- Littering in mated does, in ovulating or pregnant ones.

The total number of ova shed (CL) in ovulating females, of implanted embryos (IE) in pregnant females, and of youngs born (TNB) and born alive were analyzed, as well as the embryonic survival (IE/CL), foetal survival (TNB/IE) and prenatal survival (TNB/CL) rates.

Statistical methods

Analysis of variance was performed on all variables with the following fixed effects :

- Daylength at birth of female (increasing or decreasing),
- Daylength at mating (increasing or decreasing) with year of mating nested within this effect,
- Way of reproduction : natural mating or artificial insemination (except for acceptance of mating).
- Combination of age and mating number : the "early" group was mated four times and the "late" group was mated twice.

Frequencies were considered as "all or none" variables (0 and 1). A previous analysis showed that the effect of cohort within daylength at birth and of all interactions were not significant. Results presented in tables are least square means from this analysis.

Among pregnant does, we compared the number of ova shed by does which littered with those which did not litter, by adding to this model the all or none effect "littering".

Correlations of all the reproductive traits with total weight of fleece at the harvest preceding mating were calculated. They were residual correlations proceeding from analysis of variance of reproductive traits described earlier and analysis of variance of fleece weight with daylength at birth and harvest and age at harvest effects (according to ROCHAMBEAU *et al.*, 1991).

RESULTS

Overall means

An overall of 363 presentations was recorded (Table 1). Only 15 does refused a natural mating twice (at first presentation and 2 days later) and 13 mated does died between mating and endoscopy. So data from 335 females were available. Among them, 30 died between implantation and littering.

From 100 mated does, 84 ovulated at least one ovocyte, 53 had at least one implanted embryo and only 32 had at least one young born. So, only 63.1% of ovulating does were pregnant and only 57.5% of pregnant does littered (including only live does 30 days after mating) (Table 2).

Average litter size of littering females was 5.3 youngs born, whereas there were 9.5 ova shed and 8.3 implanted embryos (Table 3).

Table 1 : Number of data according to daylength at birth, daylength at mating, age at first mating and the reproduction way

		Daylength at birth				
		Increasing		Decreasing		
Age at first mating	Reproduction way	Daylength at mating		Daylength at mating		
		Increasing	Decreasing	Increasing	Decreasing	Overall
Early	AI	41	56	16	11	124
	NM	42	52	22	15	131
Late	AI	17	24	6	6	53
	NM	16	24	9	6	55
Overall		116	156	53	38	363

Table 2 : Effects of daylength, age at first mating and reproduction way on fertility components : ovu

	Mated does				
	Acceptance of mating	Ovulation	Implantation	Littering	Littering (at least 1 live pup)
Number of data	*186*	*335*	*335*	*305*	*305*
Overall mean (%)	87.1 ± 31.8	84.2 ± 34.2	53.1 ± 45.0	31.5 ± 45.0	26.6 ± 43.5
R^2	0.17	0.16	0.22	0.11	0.08
Daylength at birth *Increasing - Decreasing*	ns -4.3 ± 6.0	ns +0.6 ± 4.9	ns -9.6 ± 6.5	** -15.9 ± 7.0	* -12.0 ± 6.8
Daylength at mating *Increasing - Decreasing*	*** +22.8 ± 5.6	ns -4.9 ± 4.9	ns +0.8 ± 6.5	ns -9.7 ± 6.7	ns -7.8± 6.5
Year within daylength.	ns	***	***	**	*
Group of mating : Age and mating number	ns	***	***	***	**
Reproduction way *Natural mating - A.I*	-	*** -13.5 ± 3.8	ns +1.6 ± 4.9	ns -0.2 ± 5.2	ns +3.5 ± 5.0

ns : not significantly different from 0 * P<0.10 **P<0.05 ***P<0.01

Table 3 : Effects of daylength, age at first mating and reproduction way on litter size components : ovulation an

	Number of ova shed	Number of implanted embryos	Total born / litter	Born alive / litter	Born alive /live litter	Embr surv (%
Number of data	*278*	*179*	*96*	*96*	*81*	*17*
Overall mean (%)	9.5 ± 3.1	8.3 ± 3.1	5.3 ± 2.6	4.7 ± 3.1	5.6 ± 2.5	75.6 ±
R^2	0.30	0.25	0.18	0.14	0.15	0.1
Daylength at birth	ns	**	ns	ns	ns	*
Increasing - Decreasing	-0.5 ± 0.5	-1.3 ± 0.6	+0.6 ± 0.7	+0.4 ± 0.9	+0.3 ± 0.8	-10.0
Daylength at mating	ns	**	ns	ns	ns	n
Increasing - Decreasing	+0.8 ± 0.5	+1.5 ± 0.6	+0.4 ± 0.7	0	-0.2 ± 0.7	-0.6 ±
Year within daylength.	***	***	ns	ns	ns	*
Group of mating	***	ns	ns	ns	ns	n
Reproduction way	ns	***	***	***	**	*
Natural mating - A.I.	+0.6 ± 0.4	+1.3 ± 0.5	+1.5 ± 0.6	+1.9 ± 0.7	+1.2 ± 0.6	+6.9

ns : not significantly different from 0 * P<0.10 **P<0.05 ***P<0.01

Effect of daylength at birth
There was a significant effect of daylength at birth, in favour of does born in decreasing days, on frequency of littering (47.4 *vs* 31.6 %, P<0.05), embryonic survival rate (84.0 *vs* 74.0%, P<0.05) and consequently number of implanted embryos (9.04 *vs* 7.79 P<0.05), but not on frequency of ovulation or litter size.

Effect of daylength at mating
Daylength at mating had a significant effect, in favour of increasing days, on acceptation rate of naturally mated females (100 *vs* 77.2%, P<0.01) and number of implanted embryos (9.0 *vs* 7.8, P<0.05).

Effect of age and parity
There were no significant differences between average performances of does first mated early and those first mated late, except for the frequency of ovulation, in favour of the latter, and foetal survival rate, in favour of the former. However, results of the first parity of does mated early differed from all the others : the frequency of ovulation, implantation and littering were significantly poorer. The number of ova shed was significantly lower (7.2 *vs* 10.0, P<0.01), but litter size did not differ significantly (6.1 *vs* 5.2), because prenatal survival rate was significantly better (67 *vs* 46.1%, P<0.01).
The five other groups did not differ significantly between them. In particular, at the same age (6th or 8th fleece harvest), there was no effect of parity on results.

Table 4 : Effect of age at mating on reproduction performances (means ± std).

	Overall performances: Late first mating *vs* early first mating	Performances of the first early mating *vs* others
Frequencies (%):		
Ovulation	9.6 ± 4.5 **	-26.9 ±5.6 ***
Implantation	3.3 5.9 ns	-34.5 ± 7.4 ***
Littering	-5.7 ± 6.2 ns	-23.0 ± 8.0 ***
Littering (at least 1 live pup)	6.0 ± 6.0 ns	-19.7 ± 7.7 **
Implantation /ovulating does	-0.8 ± 6.1 ns	-27.8 ± 8.8 ***
Littering /ovulating does	-9.7 ± 6.9 ns	-19.3 ± 9.9 *
Littering /pregnant does	-12.0 ± 8.7 ns	-4.6 ± 16.2 ns
On pregnant does		
Means :		
Ova shed	0.1 ± 0.4 ns	-2.8 ± 0.6 ***
Implanted embryos	-0.2 ± 0.5 ns	-0.5 ± 1.0 ns
Total youngs born	-0.9 ± 0.7 ns	0.9 ±1.1 ns
Live youngs /live litter/	-0.9 ± 0.7 ns	0.5 ± 1.2 ns
Survival rates (%) :		
Embryonic survival	0.2 ± 4.4 ns	0.9 ± 8.0 ns
Fetal survival	-13.2 ± 6.9 *	15.0 ± 12.3 ns
Prenatal survival	-9.1 ± 6.0 ns	20.9 ± 10.2 **

ns : not significantly different from 0 * P<0.10 **P<0.05 ***P<0.01

Effect of reproduction way
Naturally mated does had a significantly lower frequency of ovulation (81.1 *vs* 94.6%, P<0.01), but in ovulating females, artificial insemination led to decrease the implantation rate (64.4 *vs* 73.2%, P<0.01), the litter size at implantation (7.7 *vs* 9.1, P<0.01) and at birth (3.8 *vs* 5.6 live pups, P<0.01).

Correlation with fleece weight
Analysis of variance of fleece weight showed only a very significant effect of harvest number. Residual correlations of fleece weight with reproductive traits after the fleece harvest ranged from 0.13 to -0.12 ; none of them was significantly different of zero.

DISCUSSION

We have first to underline the high mating acceptance rate (87.1%). In strains raised for meat production, the receptivity of the does is generally lower but depends on reproduction rhythms. An hypothesis could be the short delay (one week) between fleece harvest and mating, as some authors showed a favourable effect of stress on sexual receptivity (LEFEVRE and MORET, 1978 ; THEAU-CLEMENT *et al.*, 1990).

If 84.2% of does ovulated, only 26.6% of them litter at least one live pup. This result is in agreement with data of THEBAULT and ROCHAMBEAU (1988) who registered a 25% fertility for French Angora rabbits. 36.9% of ovulating does had no implanted embryos. This corresponds to fertilization lacks or early embryonic mortality. Furthermore, 42.5% of does having at least one implanted embryo did not litter. It means that after implantation, often all embryos degenerate. This abortion rate between implantation and birth is very high, as it was suspected by breeders, who observed abnormal differences between number of positive palpations and littering rate. In strains raised for meat production which were observed by endoscopy, abortions are rare events (SANTACREU *et al*, 1990). None of the effects analyzed in this work had a significant influence on abortion rate. We can only notice that aborting females had a significantly lower number of ova shed (8.7 *vs* 10.6, $P<0.01$), number of implanted embryos (7.1 *vs* 8.9, $P<0.01$) and embryonic survival rate (70.4 *vs* 84.2, $P<0.01$).

The mean number of ova or embryos counted by doe was close to BROCKAUSEN *et al.* (1979) results in German Angora rabbits. Litter size was in agreement with THEBAULT and ROCHAMBEAU (1988) (4.9 born alive), but lower than that observed by BROCKAUSEN *et al.* (1979) or EIBEN *et al.* (1996a) in German Angora rabbits.

In pregnant does, the embryonic survival rate was 75.6 %. This result is near that of EIBEN *et al.* (1996b), and is not lower to that observed in strains raised for meat production (BOLET *et al.*, 1990, 1994 ; BLASCO *et al.*, 1994). Conversely, foetal survival rate in littering does (63.7%) was quite lower. So, either partial or total, high foetal mortality is a characteristic of French Angora rabbits. We can suspect an unfavourable effect of consanguinity and, perhaps, a pleiotropic effect of Angora gene on foetal survival. Further investigations are needed.

Does born on decreasing days were more fertile and had a better embryonic survival. This result quite original, has not been yet observed. An effect of birth season on wool production was also observed by ROCHAMBEAU *et al* (1991) in the same population. They observed also that fleece weight was reduced in mated or suckling does, but, in our case, we noticed no relation between fleece weight and reproductive performances after the fleece harvest, contrary to SCHLOLAUT hypothesis (1990).

The higher acceptance rate on increasing daylength at mating is not surprising. It agrees with observations made by BOYD and MYHILL (1987) in the wild European rabbit. The number of implanted embryos was also significantly higher on increasing daylength at mating : does had 1.3 implanted embryo more, but litter size was not significantly higher. The number of ova shed was greater by 0.8 on increasing daylength, but this difference was not significant ; in the same way, THEAU-CLEMENT *et al.* (1991) found on French Angora does 1.3 corpora lutea more in February (increasing daylength) than in October (decreasing daylength), but this difference was not significant.

Our results show clearly that the traditional late first mating is not responsible for poor reproduction performances and high foetal mortality of French Angora does. Furthermore, performances of does mated early are lower in their first parity.

As observed by THEAU-CLEMENT *et al.* (1991), GnRH injection increased the ovulation frequency as compared to natural mating, but ovulation intensity did not vary with the way of ovulation induction. Conversely, implantation rate, implanted embryos and live pups were significantly higher with natural mating. Finally, the number of live youngs produced by mated does was 1.0 with artificial insemination *versus* 1.7 with natural mating. So, in our conditions, A.I did not improve reproduction performances, in spite of the high acceptance rate (THEAU-CLEMENT *et al.*, 1990).

CONCLUSION

This study allowed to state the problems of reproduction of French Angora rabbit does : we verified that there are no major problems of ovulation frequency and intensity ; for the first time, we quantified the embryonic and foetal losses. However, none of the analyzed effects had a major influence on reproductive performances. In particular, the bad performances are not explained by late mating or high fleece production. Artificial insemination does not allow to improve the performances. Further studies on the effect of Angora gene on reproduction are needed.

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REFERENCES

BLASCO A., ARGENTE M.J., HALEY C.S., SANTACREU M.A., 1994. Relationships between components of litter size in unilaterally ovariectomized and intact female does. *J. Anim. Sci.*, **72**, 3066-3072.

BOLET G., BRUN J.M., HULOT F., THEAU-CLEMENT M., 1990. Variabilité génétique et effet de la sélection dans le croisement de 3 souches de lapin. 2. Composantes biologiques de la taille de portée. *5èmes Journées de la Recherche Cunicole, Paris, 12-13 décembre 1990*, **comm. 65.**

BOLET G., SANTACREU M.A., ARGENTE M.J., CLIMENT A., BLASCO A., 1994. Divergent selection for uterine efficiency in unilaterally ovariectomized rabbits. I. Phenotypic and genetic parameters. *5th World Congress of Genetics Applied to Livestock Production, Guelph, Canada, 7-12 August 1994*, **vol. XIX**, 261-264.

BOYD I.L., MYHILL D.G., 1987. Seasonal changes in condition, reproduction and fecundity in the wild European rabbit (Oryctolagus cuniculus*). J. Zool., Lond.*, **212**, 223-233.

BROCKHAUSEN VON P., PAUFLER S., MICHELMANN H.W., SCHLOLAUT W., 1979. Untersuchung des Einflusses der Wollänge und der Schurfrequenz auf Fruchtbarkeitskriterien beim weiblichen Angorakaninchen. *Züchtungskunde*, **51(4)**, 315-325.

EIBEN C., SZENDRO Z.S., SUGAR L., ALLAIN D., THEBAULT R.G., RADNAI I., BIRONE NEMETH E., LANSKI J., 1996b. Study on the performance of normal X, Angora and their reciprocal crossbred rabbits : 1. Components of litter size. *VIth Congress of World Rabbit Science Association, July 9-12, 1996, Toulouse, France.*, (submitted for publication).

EIBEN C., SZENDRO Z.S., ALLAIN D., THEBAULT R.G., RADNAI I., BIRONE NEMETH E., LANSKI J., 1996a. Study on the performance of normal X, Angora and their reciprocal crossbred rabbits : 1. Reproduction traits. *VIth Congress of World Rabbit Science Association, July 9-12, 1996, Toulouse, France*, (submitted for publication).

LEFEVRE B., MORET B., 1978. Influence d'une modification brutale de l'environnement sur l'apparition de l'oestrus chez la lapine nullipare. *Annales de Biologie animale*, Biochimie, Biophysique **18 (3)**, 695-698.

ROCHAMBEAU H. de, THEBAULT R.G., GRUN J., 1991. Angora rabbit wool production : non genetic factors affecting quantity and quality of wool. *Anim. Prod.*, **52**, 383-393.

ROUGEOT J., THEBAULT R.G., 1989. Le lapin Angora, sa toison, son élevage. Les éditions du Point Vétérinaire, Maisons-Alfort, France, 182 p.

SANTACREU M.A., VIUDES M.P., BLASCO A., 1990. Evaluation par coelioscopie des corps jaunes et des embryons. Influence sur la taille de portée chez la lapine. *Reprod. Nutr. Dev.*, **30**, 583-

SCHLOLAUT W., 1980. *The angora rabbit.* Deutsche GTZ., GmbH Ed., pp 98.

THEAU-CLEMENT M., POUJARDIEU B., BELLEREAUD J., 1990. Influence des traitements lumineux, modes de reproduction et états physiologiques sur la productivité de lapines multipares. *5èmes Journées de la Recherche Cunicole, 12-13 Décembre, 1990, Paris*, **Tome I,** Comm. 7.

THEAU-CLEMENT M., THEBAULT R.G., BOLET G., ROCHAMBEAU H. de, 1991. La reproduction du lapin Angora de souche française : ovulation chez la femelle, production de semence chez le mâle. *Reprod. Nutr. Dev.*, **31**, 667-673.

THEBAULT R.G., ROCHAMBEAU H. de, 1988. Production data and demographic parameters of a French Angora rabbit strain. In: 4th Congr World rabbit Sci Assoc (S Holdas, ed), Budapest, October 10-14th, **2**, 227-237.

Effet de la durée d'éclairement, de l'âge à la saillie et de voie de reproduction chez des lapines Angora français - La reproduction de 158 lapines de souche Angora Français a été étudiée. Elles sont nées et mises à la reproduction en jours croissants ou décroissants, en saillie naturelle ou en insémination artificielle, soit précocément (après la 2ème, puis après les 4ème, 6ème et 8ème récolte de poil) ou tardivement (après la 6ème puis le 8ème récolte). Le taux élevé de réceptivité, 87%, est influencé seulement par la durée des jours, en faveur des jours croissants. Sur 100 femelles mises à la reproduction, 53 sont gestantes et seulement 27 mettent bas au moins un lapereau vivant. Il nait en moyenne 5,3 lapereaux, pour 9,5 ovocytes pondus et 8,3 embryons implantés, comptés par endoscopie au 12ème jour de gestation. Il n'y a pas de différence significative majeure entre femelles mises à la reproduction tardivement ou précocément, bien que les performances de ces dernières en première portée soient significativement plus faibles. En saillie naturelle, la fréquence d'ovulation est significativement plus faible (81,1 *vs* 94,6%, P<0.01), mais en insémination artificielle,on observe un taux d'implantation (64,4 *vs* 73,2%, P<0.01), un nombre d'implants (7,7 *vs* 9,1, P<0.01) et de nés vivants (3,8 *vs* 5,6, P<0.01) plus faibles. Il n'y a aucune corrélation significative entre le poids de poil produit et les performances de reproduction. Aucun des effets étudiés n'a d'influence significative sur le fort taux d'avortement. Des travaux supplémentaires sur l'effet du gène Angora sur la reproduction seraient nécessaires.