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DAM AND LITTER INBREEDING AND ENVIRONMENTAL EFFECTS ON LITTER PERFORMANCE IN BOTUCATU RABBITS

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ABSTRACT: The purpose of this study was to evaluate the effects of the inbreeding of the dam (F_d) and of the litter (F_l), parity of dam, and month and year of birth on number of young born alive (NBA) and weaned per litter (NW), total litter weaning weight (LWW), mean weaning weight (MWW) and litter pre-weaning mortality rate (LM) in Botucatu rabbits. Data on 1,065 litters were collected from 1992 to 1994 at the UNESP rabbitry located in Botucatu, SP, Brazil, and analysed by least-squares method. Litters were weaned at 30 days of age. Values of F_d and F_l ranged from zero to 0.3309 and averaged 0.0717 ± 0.0015 and 0.0979 ± 0.0018, respectively. The overall means and standard-errors of NBA, NW, LWW, MWW, and LM were 7.458 ± 0.076, 5.869 ± 0.067, 3576 ± 36 g, 626.6 ± 3.4 g, and 0.1954 ± 0.0063, respectively. Year and month of birth influenced MWW ($P < 0.001$) and tended to affect LWW ($P < 0.07$). Parity number affected ($P < 0.001$) NBA, NW and LWW. The first litter of a female presented ($P < 0.05$) lower NBA NW, and also LWW when individually compared to parities two to five. The inbreeding coefficient of the dam showed a negative linear association with NBA ($P < 0.001$), NW ($P < 0.001$), LWW ($P = 0.007$), and MWW ($P < 0.001$), but not with LM ($P = 0.576$), suggesting that the reduction in NW reflected a decrease in NBA but not an increase in LM. It was predicted that for each increment of 10 % in F_d, a corresponding reduction of 0.805 young born, 0.589 young weaned, and 211 g in LWW were observed, while MWW increased by 29.1 g. The reduction in NW (10.0 % of the overall mean of the trait) was proportionally greater than the reduction in LWW (5.9 % of the overall mean of the trait), providing a partial explanation for the increase in MWW. No effect of F_l ($P > 0.05$) was detected for any litter performance traits.

RESUME : Effets de la consanguinité des femelles et des portées ainsi que de l'environnement sur les performances des portées de lapins de Botucatu.
Le but de cette étude a été d'évaluer les effets de la consanguinité des femelles (F_d) et des portées F_l), de la parité des femelles et du mois et de l'année de naissance sur le nombre de lapereaux nés vivants (NBA) et sevrés (NW) par portée, du poids total de la portée au sevrage (LWW) du poids moyen au sevrage (MWW) et du taux de mortalité au sevrage (LM) chez les lapins de Botucatu. Les données ont été récoltées sur 1065 portées entre 1992 et 1994 dans l'élevage de l'UNSEP à Botucatu, SP, au Brésil, et analysées par la méthode des moindres carrés. Les portées ont été sevrées à 30 jours d'âge. Les valeurs de F_d et de F_l vont de zéro à 0,3309, avec une moyenne de 0,0717 ± 0,0015 et 0,0979 ± 0,0018 respectivement. Les moyennes générales et les écarts types de NBA, NW, LWW, MWW, et LM sont de 7,458 ± 0,076, 5,869 ± 0,067, 3576 ± 36 g, 626,6 ± 3,4 g, et 0,1954 ± 0,0063 respectivement. L'année et le mois de naissance influencent MWW (P<0,001) et tendent à affecter LWW (P<0,07). Le numéro de parité affecte NBA, NW et LWW (P<0,001). Les premières portées des femelles ont un nombre de lapereaux nés vivants et sevrés plus faible (P<0,05) ; il en va de même pour le poids de portée au sevrage quand il est comparé individuellement aux parités de 2 à 5. Le coefficient de consanguinité des femelles montre une liaison linéaire négative avec le nombre de nés vivants (P<0,001), NW (P < 0,001), LWW (P = 0,007), et MWW (P< 0,001), mais pas avec le taux de mortalité naissance-sevrage (P = 0,576), suggérant que la diminution de nombre de sevrés découle de celle des nés vivants et non d'une augmentation de la mortalité. Pour chaque augmentation de 10% du taux de consanguinité F_d, il y a une réduction correspondante de 0,805 lapereau né, 0,589 lapereau sevré et 211 g du poids de portée au sevrage tandis que le poids moyen au sevrage augmente de 29,1 g. La réduction de NW (10% de la moyenne générale de ce paramètre) est proportionnellement plus grande que la diminution de LWW (5,9% de la moyenne générale du paramètre) donnant une explication partielle de l'augmentation de MWW. Aucun effet de F_l n'a été détecté pour aucun des critères de performance de la portée.

INTRODUCTION

Inbreeding is caused by mating of individuals whose relationship is larger than the average relationship in the population (FALCONER, 1989). Direct consequences include increased homozygosity, due to common ancestry, and probability of expression of deleterious recessive alleles. It is largely accepted that inbreeding reduces the mean of fitness traits (i.e. those related to reproduction and survival) and leads to a loss of general vigour and fertility (BOWMAN and FALCONER, 1960; LUCOTTE *et al.*, 1974; BAYON *et al.*, 1985; DECKARD *et al.*, 1989). Thus, inbreeding by itself should be avoided, although it may occur as a consequence of selection programs in elite herds, such as in the production of lines for subsequent crossbreeding.

Empirical evidence suggests that moderate inbreeding is present in small and medium-sized commercial rabbit production units in Brazil, either due to the reduced number of breeding bucks, or to lack of replacement of breeding bucks at the proper time, or a combination of both. No effects of moderate inbreeding of the doe or of the young (0.0107 and 0.0479, on average) were detected for litter traits in descendants of Norfolk rabbits (NUNES and POLASTRE, 1988, 1990). However, FERRAZ *et al.* (1991) working with New Zealand and Californian rabbits reported a reduction in litter sizes and weights at 21 days of age and at weaning, as the inbreeding coefficient of the doe increased (range of zero to 0.26). The objective of this study was to evaluate the effects of the inbreeding coefficients of the dam (**F_d**) and of the litter (**F_l**) on litter pre-weaning performance in a closed population under selection, but with mating pairs formed randomly. Secondly, parity, month and year of parturition effects on the same traits were also evaluated.

MATERIAL AND METHODS

Animals and management

Data collection was conducted at the Rabbit Production Unit at UNESP, Botucatu - SP, Southeast Brazil (at 22° South latitude), from January 1992 to July 1994. The Botucatu rabbit population consists of a contemporary group of approximately 120 dams and 15 sires, descendants from 30 (five bucks and 25 does) Norfolk 2000 hybrids imported from "Norfolk Rabbits Limited", England, in 1971. According to the information provided by the exporter, these hybrids originated from two generations of crossbreeding: New Zealand White X Californian crossbred does were mated to Bouscat Giant bucks. Non-systematic selection and avoidance of matings between close relatives were practised during approximately 20 generations up to 1991. In January 1992, a selection program was initiated based on the multivariate index proposed by POLASTRE *et al.* (1989) to improve direct litter and individual performance. The following traits were involved in the index: number weaned, litter weaning weight and individual weaning and 70-day weights. Approximately 20 % of the females and 3% of the males were first selected according to the index at 70 days of age. Prior to reproduction these animals were inspected; those presenting health problems or visible defects were culled.

An open east-west oriented building housed all males, females and young suckling rabbits in commercial wire cages (0.80 x 0.60 x 0.45 m) fitted with metal feeders and nipple drinkers. Light, ventilation, and temperature were natural except for a plastic adjustable curtain protecting against a predominant south wind. A pelleted ration containing approximately 18 % CP, 2750 kcal/kg DE and 12 % CF was available on an "ad libitum" basis to does and kits during lactation and restricted to about 120 g per day to bucks and non-lactating does. Major feed ingredients were corn, soybean meal, grass hay, and mineral and vitamin supplements.

Males and females were first mated at 150 and 120 days of age, respectively. Ventral palpation was performed 10 to 12 days after mating to determine pregnancy. Does that failed to conceive were remated on the next weekday. Parturition-mating interval was 10 to 15 days. Each breeding buck hutch was adjacent to eight female cages. The females from those cages were mated to the same buck for 40 days. Males were then moved to the next group of females. This rotation of males was repeated every 40 days to assure that mating pairs were randomly formed. Because the effects of inbreeding on litter traits were under investigation, sib and parent-offspring matings were not avoided. Culling criteria for does and bucks included reproductive failure and health problems such as sore hocks, respiratory problems, wry neck and abscesses. Litters were weaned at 30 days of age when the number weaned and pre-weaning mortality were recorded. Young rabbits were individually weighed and identified.

Statistical analyses

Pedigree records were not available between 1971 and 1987. A computer program developed by POLASTRE *et al.* (1992) was used to compute inbreeding coefficients according to WRIGHT (1922) and MALECOT (1948).

Data on 1,065 litters, which had at least one young weaned, produced by 296 does and 86 bucks, were analysed by least-squares using the GLM procedure of SAS (1989). The dependent variables were litter traits known to have economic importance in meat rabbit production: number of young born alive per litter (NBA), number of young weaned per litter (NW), litter weaning weight (LWW), mean weaning weight (MWW), and litter pre-weaning mortality rate (LM). Because the distribution of the latter variable deviates from normality, a transformation was used as proposed by FERRAZ *et al.* (1991)

$$X = \text{arc sin} \sqrt{LM}$$

The model for all traits included the fixed effects of dam parity, month and year of birth as well as the partial linear regression coefficients of the specific dependent variable on the dam and litter inbreeding coefficient. All possible interactions between the independent variables were included in a complete model. If found to be non-significant in a preliminary analysis, any interaction effect was omitted from the final model and a simple first order model was adopted, as follows

$$Y_{ijkl} = \mu + M_i + A_j + P_k + b_1(W_{ijk} - \overline{W}) + b_2(X_{ijk} - \overline{X}) + e_{ijkl}$$

where Y_{ijkl} = observed value of a given dependent variable; μ = overall adjusted mean; M_i = fixed effect of the i^{th} month of birth; A_j = fixed effect of the j^{th} year of birth; P_k = fixed effect of the k^{th} parity of the dam; b_1 and b_2 = partial linear regression coefficients of the specific dependent variable on dam and litter inbreeding coefficients, respectively; W_{ijk} and X_{ijk} = dam and litter inbreeding coefficients, pertaining to Y_{ijkl}; e_{ijkl} = random error associated with each observation Y_{ijkl}.

Table 1 : Means, standard deviations and ranges for litter performance traits[a] and dam (F_d) and litter (F_l) inbreeding coefficients (N=1,065)

Variable	Mean	SD	Min	Max
NBA	7.458	2.474	1	16
NW	5.869	2.202	1	12
LWW (g)	3576	1186	310	6515
MWW (g)	626.6	109.5	257	1047
LM	0.1954	0.2042	0.0000	0.9090
F_d	0.0717	0.0497	0.0000	0.3309
F_l	0.0979	0.0575	0.0000	0.3309

[a] NBA = number born alive, NW = number weaned, LWW = total litter weaning weight, MWW = mean weaning weight, LM = litter mortality, F_d = inbreeding coefficient of the dam, F_l = inbreeding coefficient of the litter.

Table 2 : Analysis of variance results for litter size-related traits[a]

Source of variation	df	Mean squares (Probability)		
		NBA	NW	LM
Year of birth	2	0.158 (0.973)	0.584 (0.879)	0.0092 (0.801)
Month of birth	11	5.471 (0.487)	4.745 (0.401)	0.0566 (0.186)
Parity number	7	36.566 (0.000)	37.093 (0.000)	0.0379 (0.498)
Dam inbreeding	1	135.433 (0.000)	72.537 (0.000)	0.0130 (0.576)
Litter inbreeding	1	11.600 (0.155)	12.654 (0.095)	0.0031 (0.786)
Error	1042	5.736	4.524	0.0416

[a] Refer to Table 1 for definition of trait abbreviations

Table 3 : Analysis of variance results for litter weight traits[a]

Source of variation	df	Mean squares (Probability)	
		LWW	MWW
Year of birth	2	3450661 (0.068)	80541.7 (0.001)
Month of birth	11	3114764 (0.055)	38774.4 (0.000)
Parity number	7	15913899 (0.000)	7134.2 (0.734)
Dam inbreeding	1	9329911 (0.007)	177173.4 (0.000)
Litter inbreeding	1	4653630 (0.057)	10.9 (0.976)
Error	1042	1283124	11379.2

[a] Refer to Table 1 for definition of trait abbreviations

Only litters with at least one young weaned were included in the analysis for litter traits, but all the parturitions of a dam were taken into account for its parity number determination. Most females were culled before the ninth parturition, either due to decreased productivity or to some alteration in their health status. Therefore, the number of records on the ninth and further parities was small giving poor estimation of the least-squares means for those classes. For this reason, ninth and further parities were omitted from the final analysis. Parity means were compared using Tukey's method. A pre-planned contrast of a predominantly cool and dry season (April to September) and a warm and more humid season (October to March) was performed as recommended by DEPRES *et al.* (1996) under tropical conditions.

An additional analysis using the same statistical model was conducted with a subset of data in order to assess parity effects more accurately. It included 319 litters from 46 does which were still alive at the weaning of their eigth litter, so that the performance of the same does were followed through eigth parities.

RESULTS AND DISCUSSION

Means, standard deviations, maximum and minimum values for the litter traits under study and also for F_d and F_l are given in Table 1. Analysis of variance results for the dependent variables are summarised in Tables 2 and 3. Interpretation of the analyses of LM was identical to the transformed variable X, making unnecessary the presentation of both. Results given pertain to the original variable (LM) exclusively.

Year and month of birth strongly affected MWW and had a tendency to affect LWW, but not prolificacy traits (Tables 2 and 3). These results suggest that year and month effects on LWW and MWW may be independent of litter size. Adjusted year and month of birth means are presented in Tables 4 and 5 and illustrated in Figures 1 and 2 for LWW and MWW. Because 1994 data is not complete and also because year is not repeatable, there is only limited interest in its effects. Month effects, on the other hand, can be mainly attributed to seasonal variation in temperature, humidity, photoperiod, and dry forage composition, but no consistent month trend could be established either for LWW or for MWW based on month to month comparisons. Similar results were obtained by LUKEFAHR *et al.* (1983a,b). A pre-planned contrast of a predominantly cool and dry season (April to September) and a warm and more humid season (October to March), however, revealed a favourable effect ($P < 0.001$) of the former on litter weight performance traits (LWW and MWW), probably due to more comfortable temperature and relative humidity ranges observed during this period (Figure 5). In contrast with the results presented here, DEPRES *et al.* (1996) described a specific detrimental effect of the hot and wet season on prolificacy traits, but temperature conditions seemed to be more severe in Guadeloupe.

Table 4 : Year of birth least–square means and standard errors

Year of birth	Number of records	NBA	NW	LWW	MWW	LM
1992	426	7.49 ± 0.14	6.01 ± 0.13	3661 ± 68	624.2 ± 6.4	0.1851 ± 0.0123
1993	510	7.51 ± 0.11	5.94 ± 0.10	3601 ± 52	623.7 ± 4.9	0.1905 ± 0.0094
1994	129	7.45 ± 0.27	6.02 ± 0.24	3911 ± 130	671.5 ± 12.2	0.1757 ± 0.0234

Table 5 : Month of birth least-square means and standard errors

Month of birth	Number of records	NBA	NW	LWW	MWW	LM
Jan	104	7.54 ± 0.25	5.76 ± 0.22	3430 ± 117	623.0 ± 11.3	0.2225 ± 0.0211
Feb	133	7.41 ± 0.22	5.78 ± 0.19	3535 ± 103	625.7 ± 9.9	0.2001 ± 0.0186
Mar	88	7.76 ± 0.26	5.94 ± 0.23	3542 ± 124	614.1 ± 11.9	0.2204 ± 0.0223
Apr	58	7.24 ± 0.33	5.86 ± 0.30	3601 ± 157	625.8 ± 15.1	0.1728 ± 0.0283
May	59	7.39 ± 0.33	6.10 ± 0.29	3941 ± 156	656.8 ± 15.0	0.1510 ± 0.0281
Jun	63	6.94 ± 0.32	5.99 ± 0.28	3888 ± 151	663.9 ± 14.5	0.1320 ± 0.0271
Jul	70	7.86 ± 0.31	6.49 ± 0.27	4025 ± 146	625.2 ± 14.1	0.1590 ± 0.0263
Aug	79	7.48 ± 0.29	5.84 ± 0.26	3783 ± 138	661.5 ± 13.2	0.2095 ± 0.0248
Sep	88	7.47 ± 0.28	6.09 ± 0.25	4000 ± 134	675.7 ± 12.8	0.1703 ± 0.0241
Oct	92	7.45 ± 0.28	6.03 ± 0.25	3542 ± 131	607.4 ± 12.6	0.1769 ± 0.0236
Nov	104	7.37 ± 0.27	5.65 ± 0.24	3560 ± 127	642.6 ± 12.2	0.2131 ± 0.0228
Dec	127	7.90 ± 0.25	6.32 ± 0.22	3842 ± 117	621.3 ± 11.2	0.1777 ± 0.0211

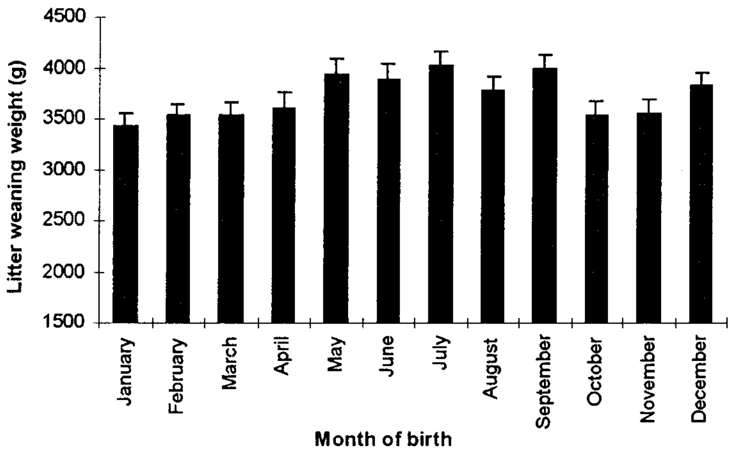

Figure 1 : Month of birth least-squares means and standard errors for litter weaning weight

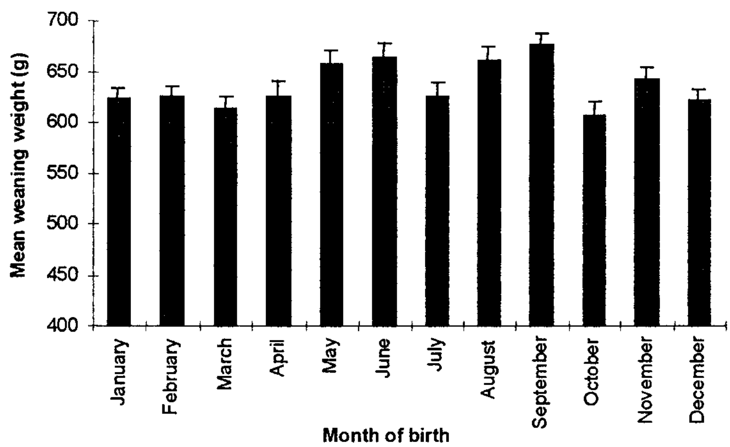

Figure 2 : Month of birth least-squares means and standard errors for mean weaning weight

Parity number was the most important environmental factor influencing litter traits. It affected prolificacy (NBA and NW) as well as LWW, but not MWW or LM (Tables 2 and 3). Parity least-squares means are presented in Table 6. Because all the data available was included in this analysis, the number of litters decreased as the parity number increased. The first litter of a female presented lower NBA, NW and LWW when individually compared to each one of parities two to five ($P < 0.05$). There was an increase of 1.1 young born alive (16%), 0.92 young weaned (18%), and 594 g (19%) in LWW from first to second parity. These results are compatible with those of ROUVIER *et al.* (1973) and similar to the trends previously reported in the Selecta rabbit strain (POLASTRE, 1990; MOURA *et al.*, 1991), and in Hungarian and Danish rabbits (JENSEN *et al.*, 1996). Rabbit does are in negative energy balance during lactation due to insufficient feed intake (PARTRIDGE *et al.*, 1983). In primiparous does, this problem is likely to be aggravated by the simultaneous need to meet body growth and reproduction energy requirements (MAERTENS, 1998). The net result could be reduced prolificacy, which combined with lower milk production in the first lactation, could be responsible for lighter litters at weaning (LUKEFAHR *et al.*,

Table 6 : Parity of dam least-square means and standard errors

Parity number	Number of records	NBA	NW	LWW	MWW	LM
1	251	6.62 ± 0.17a	5.09 ± 0.15a	3132 ± 78a	630.8 ± 7.4	0.2036 ± 0.0141
2	226	7.68 ± 0.18b	6.01 ± 0.16b	3727 ± 83bc	639.0 ± 7.8	0.2000 ± 0.0150
3	172	7.80 ± 0.20b	6.42 ± 0.18b	4050 ± 94c	652.0 ± 8.8	0.1618 ± 0.0169
4	128	7.70 ± 0.23b	6.06 ± 0.20b	3761 ±109bc	636.7 ± 10.2	0.2012 ± 0.0195
5	90	8.17 ± 0.28b	6.64 ± 0.24b	4084 ± 130bc	635.6 ± 12.3	0.1801 ± 0.0235
6	81	7.08 ± 0.28ab	5.65 ± 0.25ab	3529 ± 133ab	636.2 ± 12.5	0.1819 ± 0.0239
7	63	7.36± 0.32ab	5.99 ± 0.28b	3700 ±150bc	642.7 ± 14.1	0.1703 ± 0.0270
8	54	7.44 ± 0.34ab	6.04 ± 0.30b	3809 ± 160bc	645.4 ± 15.0	0.1714 ± 0.0288

1983a; SINGH, 1996). Based on the results involving a synthetic strain of rabbits, RAFEL *et al.* (1990) suggested that the performance of the first litter of a female be considered separately from further parities, as distinct traits in an analysis. Our results reinforce this idea.

The evolution of parity effects on NBA, NW and LWW for the 46 dams followed through eight parturitions is illustrated in Figures 3 and 4. The pattern is similar for all three traits, suggesting an increase in performance from first to second parities, a plateau between second and fifth parities, followed by a decrease in sixth and a slight increase afterwards. A possible explanation for the apparent slight increase in performance after the sixth parturition could be an random heterogeneous distribution of parities within months or seasons.

The partial linear regression coefficients of litter performance traits on F_d and F_l are shown in Table 7. The inbreeding coefficient of the dam was linearly and negatively associated with NBA, NW, and LWW, but linearly and positively associated with MWW (Tables 2 and 3). Pre-weaning mortality did not show a consistent linear change with F_d. These results might indicate, although not measured objectively, that any improvements of NW and LWW resulting from artificial selection may have been masked by inbreeding depression. On average, a reduction of 0.805 young per litter at birth (-11%) and 0.589 young per litter at weaning (-10%) was observed for each 10 % increase in F_d. An average reduction of 211 g in litter weaning weight (-6%) also occurred for every 10 % increase in F_d, while MWW increased 29.1 g (+5%). The increase in the latter trait may have been due to the sharp decrease in litter size since smaller litters at birth result in less competition for milk increasing individual weight at weaning. Accordingly, the reduction in LWW, as a percentage of the trait mean, was proportionally less than in NBA and NW. Overall, the positive effect of F_d on individual body weight may be superficial because of the simultaneous negative effect on litter size. Because both NBA and NW, but not LM, were depressed by increasing F_d, the reduction in NW and LWW can be mainly attributed to a decrease in NBA rather than in pre-weaning survival. Mortality of zygotes pre- or post-implantation and unfavourable uterine effects were determined as the main inbreeding depression effects on litter size in rabbit inbred lines (CHAI, 1969).

These results involving inbreeding of dam effects are in agreement with reports by CHAI (1969) and PARK *et al.* (1991) who noted a consistent reduction in litter size at birth and at weaning as a consequence of inbreeding. FERRAZ *et al.* (1991) also reported a decline in litter size and weight at 21 days of age and at weaning resulting from inbreeding in New Zealand White and Californian rabbits in Brazil. Also comparable are the findings of LEE *et al.* (1991), who reported negative effects of dam inbreeding on litter size and litter weaning weight. In contrast, NUNES and POLASTRE (1988, 1990) working with early generations (between 1973 and 1974) of this same population, did not find evidence of changes in litter traits associated with inbreeding, although F_d and F_l were moderate in that study, averaging 4.79 and 1.07 %, as compared to present average values of 9.8 and 5.8 %, respectively (Table 1).

There was no significant effect of F_l on any of the litter traits, although it approached significance for NW and LWW (Table 7). Furthermore, numerical changes in NBA and NW somewhat paralleled changes that occurred with increased F_d. FERRAZ *et al.* (1991) observed reduced litter size and weight at 21 days as a consequence of increased inbreeding coefficient of the litter.

Table 7 : Partial linear regression coefficients of litter traits on dam inbreeding coefficient (b_1) and on litter inbreeding coefficient (b_2) [a]

Trait	b_1 ± s.e. (Probability)	b_2 ± s.e. (Probability)
NBA	-0.0805 ± 0.0166 (0.000)	-0.0189 ± 0.0133 (0.155)
NW	-0.0589 ± 0.0147 (0.000)	-0.0197 ± 0.0118 (0.095)
LWW (g)	-21.12 ± 7.83 (0.007)	-12.00 ± 6.30 (0.057)
MWW (g)	2.910 ± 0.738 (0.000)	0.018 ± 0.010 (0.975)
LM	-0.00079 ± 0.00141 (0.576)	0.00031 ± 0.00113 (0.787)

[a] refer to Table 1 for definition of trait abbreviations

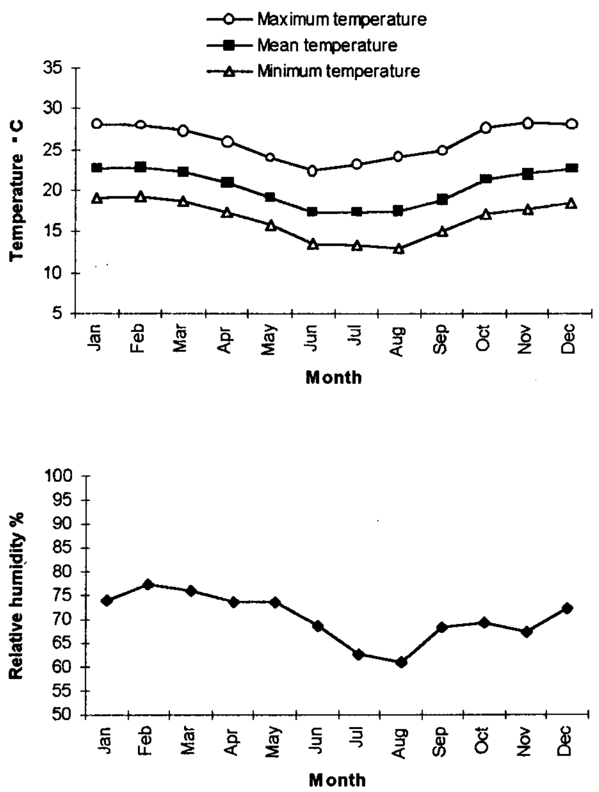

Figure 5 : Monthly variation in maximum, mean and minimum temperatures and relative humidity from 1992 to 1994

In conclusion, parity number had a marked influence on prolificacy whereas month and year of birth affected litter weight traits rather than prolificacy. In general, performance was depressed in the first litter of a female. An increase in dam inbreeding coefficient linearly depressed prolificacy, decreasing litter size at birth and weaning as well as litter weaning weight. The positive effect of dam inbreeding on mean weaning weight may have been masked by the sharp decrease in litter size at weaning due to this same effect. Evaluation of litter performance traits in nucleus populations should include dam inbreeding information in the model; otherwise, the expected merit of a parent with a large number of inbred progeny could be underestimated. The effect of litter inbreeding was not as important.

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REFERENCES

BAYON Y., FUENTE L.F., SAN PRIMITIVO F., 1985. [Inbreeding and effective number in five mouse lines submitted to selection for prolificacy or body weight]. *An. Fac. Vet. Leon, 31, 133-41.*

BOWMAN J.C., FALCONER D.S., 1960. Inbreeding depression and heterosis of litter size in mice. *Genet. Res., 1, 262-274.*

CHAI C.K., 1969. Effects of inbreeding in rabbits. *J. Hered., 60(2), 64-70.*

DECKARD B.S., WILSON J.R., SCHLESINGER K. 1989. Behavioural and reproductive differences in mice as a function of inbreeding. *Behav. Genet., 19(3), 433-445.*

DEPRES E., THEAU-CLEMENT M., LORVELEC O., 1996. Effect of the genotype, day length, season, and physiological stage on the reproductive performance of doe rabbits reared in Guadeloupe. *World Rabbit Sci., 4(4), 181-186.*

FALCONER D.S., 1989. Introduction to quantitative genetics. *3rd ed., Longman, London, England.*

FERRAZ J.B.S., JOHNSON R.K., ELER J.P. 1991. Effect of inbreeding on reproduction traits of Californian and New Zealand White Rabbits. *J. Appl. Rabbit Res., 14(4), 211-216.*

JENSEN J. A., SZENDRÖ Zs., SORENSEN P. 1996. Diallel crossbreeding experiment in Danish and Hungarian meat rabbits. 2. Quality evaluation, dissection, and chemical analysis of carcasses. *World Rabbit Sci., 4(3), 115-120.*

LEE H.K., YOO C.H., CHOI J.S., PARK T.J., 1991. [Inbreeding effect of pre-weaning traits in rabbits]. *Anim. Breed. Abstr., 59(7). (Abstr. 5155)*

LUCOTTE G., KOBOZIEFF N., GEMAHLING E., 1974. Influence de la consanguinité frere x soeur sur la taille de la premiére portée chez la souris. *C. R. Seances Soc. Biol. Fil., 168(8-9), 933-936.*

LUKEFAHR S., HOHENBOKEN W.D., CHEEKE P.R., 1983a. Characterisation of straightbred and crossbred rabbits for milk production and associative traits. *J. Anim. Sci. 57, 1100-1107.*

LUKEFAHR S., HOHENBOKEN W.D., CHEEKE P.R., PATTON N.M., 1983b. Doe reproduction and pre-weaning litter performance of straightbred and crossbred rabbits. *J. Anim. Sci.,57, 1090-1099.*

MAERTENS L. 1998. Fats in rabbit nutrition: a review. *World Rabbit Sci., 6(3-4), 341-348.*

MALECOT G. 1948. Les mathematiques de l'heredité. *Masson et Cie, Paris, France.*

MOURA A.S.A.M.T, POLASTRE R., NUNES J.R.V., 1991. Genetic study of litter traits at weaning in Selecta rabbits. *J. Appl. Rabbit Res.,14(4), 222-227.*

NUNES J.R.V., POLASTRE R., 1988. [Effects of inbreeding and environmental factors on the reproduction of Norfolk hybrid rabbits]. *Arq. Bras. Med. Vet. Zootec.,40(2), 125-136.*

NUNES J.R.V., POLASTRE R., 1990. [Effects of environmental factors and inbreeding on weaning traits of Norfolk hybrid rabbits]. *Arq. Bras. Med. Vet. Zootec., 42(5), 407-425.*

PARK Y.I., HONG S.H., KIM J.J., KIM N.H., 1991. [A study on the effect of inbreeding on the performance of Angora rabbits]. *Anim. Breed. Abstr., 59(5). (Abstr. 3672).*

PARTRIDGE, G.G., FULLER M.F., PULLAR J.D., 1983. Energy and nitrogen metabolism of lactating rabbits. *Br. J. Nutr., 49, 507-516.*

POLASTRE R., 1990. [Selection for litter and individual growth performance in rabbits: estimation and weighing of direct and maternal genetic effects]. *Associate Professor Dissertation, Faculdade de Medicina Veterinaria e Zootecnia da UNESP, Botucatu, Brazil.*

POLASTRE R., CAMPAGNA R.C., MOURA A.S.A.M.T., COSTA A.R.C., 1992. [A computer program for the recording and selection of meat rabbits]. *in: Proc. 29th Reunião Anual Da Sociedade Brasileira De Zootecnia, , Lavras July 1992, 459 (Abstr.).*

POLASTRE R., MOURA A.S.A.M.T., PONS S.B., CARMELO M.J., 1989. [A selection index to improve direct litter and individual weight traits in rabbits]. *in: Proc. 26th Reunião Anual Da Sociedade Brasileira De Zootecnia, , Porto Alegre July 1989, 348 (Abstr.).*

RAFEL O., TRAN G., UTRILLAS M., RAMON J., PERUCHO O., DUCROCQ V., BOSCH A., 1990. Sélection pour un objectif global (poids de portée à 60 jours) en générations chevauchantes dans une lignée blanche synthétique de lapins. Etude de la variabilité non génétique de la taille et du poids de portée à différents stades. *Options Méditerranéennes - Série Séminaires -* ***8****, 75-82.*

ROUVIER R., POUJARDIEU B.; VRILLON J.L., 1973. Analyse statistique des performance d'elevage des lapines. Facteurs du milieu, correlations, repetabilites. *Ann. Genet. Sel. Anim.,* ***5****, 83-107.*

SAS Institute. 1989. SAS/STAT® User's guide. *SAS Inst. Inc., Cary NC, USA.*

SINGH G., 1996. Genetic and non-genetic factors affecting milk yield of rabbit does under hot semi-arid climate. *World Rabbit Sci.,* ***4(2), 79-84.***

WRIGHT S., 1922. Coefficients of inbreeding and relationship. *Am. Nat.,* ***56****, .330-338.*