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ESTIMATION OF DOE BREEDING VALUES FOR LITTER TRAITS OF THREE STANDARD BREEDS OF RABBITS RAISED UNDER COMMERCIAL INTENSIVE SYSTEM OF PRODUCTION IN EGYPT

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*Data on 355 does gave 1430 purebred litters of Bouscat **(B)**, Californian **(CAL)** and New Zealand White **(NZW)** rabbits were used to quantify doe variance components and repeatability values for litter size at birth **(LSB)**, litter weight at birth **(LWB)** and mean bunny weight per litter at birth **(MBWB)**, 21-day litter size **(LS21)**, 21-day litter weight **(LW21)**, mean bunny weight per litter at 21 days **(MBW21)**, weaning litter size **(LSW)**, weaning litter weight **(LWW)**, mean bunny weight per litter at weaning **(MBWW)** and gain in litter weight up to 21 days **(LG21)** and up to weaning **(LGW)**. The common litter effects on these litter traits were investigated for each breed separately. Doe breeding values **(DBV)** were predicted for these traits using a single-trait Animal Model **(AM)**.*

*Estimates of doe variance component for litter traits, in general, were low or moderate and they were higher in **B** rabbits than in **CAL** and **NZW** ones. Common litter effect showed significance on litter traits in **B** and **NZW** rabbits except **LW21** and **LG21** in **NZW** rabbits, while did not prove significance on most litter traits of **CAL** rabbits. Percentages of variance component of common litter effect for most litter traits were low or moderate. Repeatability estimates for these traits were also low or moderate. Estimates in **B** rabbits were relatively higher than those in **NZW** and **CAL** rabbits. Percentages of does having positive estimates of **DBV** for litter traits were mostly less than 50%. In general, **DBV** ranged from -1.31 to 1.08 young for litter size traits, from -385.7 to 494.3 grams for litter weight traits, from -61.9 to 84.6 grams for mean bunny weight per litter traits and from -356.1 to 448.5 grams for gain in litter weight traits. The ranges in **DBV** for most litter traits in*

B rabbits were relatively higher than those of NZW and CAL rabbits, i.e. does of B rabbits ranked first in DBV followed by NZW and CAL.

Key words:Litter traits, common litter effect, variance component, doe breeding value, repeatability, Animal Model.

New standard breeds of rabbits were imported to Egypt during the last two decades (e.g. Bouscat, Californian and New Zealand White) for establishing different enterprises of intensive commercial rabbit production for meat. Till now, there are insufficient information about the genetic potentialities of these breeds under the commercial Egyptian conditions. This calls for carrying out intensive research work on these breeds to quantify the genetic aspects that control their productivity.

Genetic evaluation in rabbits was recently performed using the Animal Model which requires accurate and good estimates of variance components (Baselga *et al.*, 1992; Ferraz *et al.*, 1992; Ferraz and Eler, 1994; Reverter *et al.*, 1994; Gomez *et al.*, 1996; Ahmed, 1997; El-Raffa *et al.*, 1997). In most cases, variance components for litter traits in rabbits were estimated by Restricted Maximum Likelihood (**REML**) method. During the last decade, **BLUP** under methodology of Animal Model is becoming the preferred method for animal breeders to evaluate their animals (Henderson, 1988).

The present work was set up in an intensive commercial herd of rabbit production using Bouscat, Californian and New Zealand White rabbits in order: (1) to quantify doe components of variance and repeatabilities for litter traits using **REML** method and (2) to predict the breeding values of these traits for does raised under such intensive system of production in Egypt using a single-trait Animal Model.

MATERIAL AND METHODS

This work was carried out at the farm of San El-Hager Agricultural Company, San El-Hager, Sharkia Governorate, Egypt, during two successive years of production which started in January 1992. The animals used in this study were the descendant of Bouscat (**B**), Californian (**CAL**) and New Zealand White (NZW) rabbits. These breeds were imported by San El-Hager Agricultural Company from Hungary in 1991.

Animals and breeding plan:

At the beginning of the work, breeding females within each breed were grouped at random into groups ranging from 3 to 5 does according to the available numbers. A buck from the same breed was assigned at random for mating each group of does with a restriction of avoiding parent-offspring, full-sib and half-sib matings. Each buck was allowed to sire all his litters from the same assigned females-group. Culled does and bucks or dead ones during the experimental period were replaced randomly by their substitutes from the original stock. Number of the breeding does and bucks of the three breeds used in the two years are represented in the following Table.

Distribution of does and bucks in the two years of the study.

Year	Bouscat		Californian		New Zealand White	
	Doe	Buck	Doe	Buck	Doe	Buck
1st	65	17	14	5	37	10
2nd	146	40	51	14	139	40
Total	211	57	65	19	176	50

Rabbitry, housing and management:

Rabbits of the study were raised in double-tier battaries of pyramid type (California battery) in closed rabbitry. The rabbitry is air-conditioned to keep temperature inside the rabbitry between 20-24° c all the year round. Above each row of batteries, there were eight florescent lamps at about 75-100 cm above the battery for providing a light rate of 40 watt. Breeding does and bucks were housed individually in galvanized wire cages of such Californian type battaries. The cages of does were provided with external metal nest boxes for delivering and nursing progeny during the suckling period. All cages of does and bucks were equipped with feeding hoppers and automatic drinkers.

Matings were carried out naturally. Each doe was transferred to the cage of the assigned buck to be bred and returned back to its cage after mating. Pregnancy was determined by palpation 10 days after mating. Does that failed to conceive were returned to the same assigned buck to be rebred. All does were rebreed from the same assigned bucks within 12 hours after each kindling. On the 25th day of pregnancy, the nest boxes were supplied with rice straw. Within 12 hours after kindling, litters were checked and recorded for size and weight. Thereafter, litters in the nest were examined each morning during the suckling period to remove the dead young.

Young rabbits were weaned at 30 days after kindling and transferred to another building to be housed in groups of 2-3 individuals in standard progeny wire cages equipped by feeding hoppers and drinking nipples.

Feeding and ration:

Rabbits were always fed *ad-libitum* all year round on a commercial pelleted rabbit ration. The composition of that ration was 18% crude protein, 3% ether extract, 14% crude fiber, 2% mineral mixture (1% Ca, 0.7% P, 0.3 Na) and 63% soluble carbohydrates. The digestible energy was 2600 Kcal/Kg of ration. Fresh clean water was available all time.

Data:

Data collected on doe litter traits being litter size at birth, 21 days and weaning (**LSB, LS21, LSW**, respectively), litter weight at birth, 21 days and at weaning (**LWB, LW21, LWW**, respectively), mean bunny weight per litter at birth, 21 days and at weaning (**MBWB, MBW21, MBWW**, respectively) and gain in litter weight up to 21 days and up to weaning (**LG21, LGW**, respectively). Records of litters at kindling were taken within 12 hours from kindling, while other records were taken in time. All weights were recorded to the nearest gram.

Models of analysis:

Doe litter traits of each breed were analyzed separately using the Mixed Model Least-Squares and Maximum Likelihood Mean Weighted program of Harvey (1990). The following doe model was used.

$$Y = X B + Z_a A + e \quad \text{(Model 1)}$$

where:

Y = vector of observation of doe trait,

X = Incidence matrix for fixed effects,

B = vector of an overall mean and fixed effects (year-season combination, parity),

Z_a = Incidence matrix for random effects (direct genetic effect),

A = vector of direct genetic effect of the doe and

E = vector of random error.

Repeatability estimate for each trait was calculated as the doe intra-class correlation (t_d), i.e. $t_d = \frac{\sigma_d^2}{\sigma_d^2 + \sigma_e^2}$, where σ_d^2 and σ_e^2 are the variance component for doe and error estimated by **REML** procedure, respectively.

To detect the random common litter effect (combination effect of dam of the doe and the parity in which the doe was born) on doe litter traits, data were reanalyzed for each breed separately using the following mixed model:

$Y = XB + Z_c C + e$ ....(Model 2)

where:

Z_c = Incidence matrix for common litter effect,

C = vector of common litter effect,

E = vector of random error and the other symbols of Model 2 were as defined before in Model 1.

The intra-class correlations of the common litter effects (t_c) for different litter traits were calculated as: $t_c = \frac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2}$, where σ_c^2 and σ_e^2 are the variance components for the common litter effect and error estimated by **REML** procedure, respectively.

Prediction of doe breeding values:

The repeatability estimates for litter traits (t_d) obtained by **REML** procedure (Model 1) were used as guessed values in calculation of the breeding values for does. The estimates of the breeding values for litter traits were predicted for does of each breed separately using the Animal Model (**AM**) written by Misztal (1990). The following Animal model was used (in matrix notation):

$$\begin{bmatrix} X'X & X'Z_d & X'Z_c \\ Z'_dX & Z'_dZ_d + K_dA^{-1} & Z'Z_c \\ Z'_cX & Z'_cZ & Z'_cZ_c + K_cI \end{bmatrix} \begin{bmatrix} \hat{B} \\ \hat{d} \\ \hat{c} \end{bmatrix} = \begin{bmatrix} X'Y \\ Z'_dY \\ Z'_cY \end{bmatrix}$$

where: $K_d = -\left(\frac{1-t_d}{t_d}\right)$ and $K_c = \left(\frac{1-t_c}{t_c}\right)$ since t_d = repeatability of the doe trait and t_c = intra-class correlation for common litter effect for the same trait.

Since Var (d) = $A\sigma_d^2$, Var (c) = $I_c\sigma_c^2$ and Var (e) = $I_e\sigma_e^2$, consequently, variance-covariance matrix of the random effects can be represented as follows:

$$Var\begin{bmatrix} d \\ c \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_d^2 & 0 & 0 \\ 0 & I_c\sigma_c^2 & 0 \\ 0 & 0 & I_e\sigma_e^2 \end{bmatrix}$$

where:

A = Numerator relationship coefficient matrix,

I_c = an identity matrix with order equal to number of does and

I_e = an identity matrix with order equal to number of records.

RESULTS AND DISCUSSION

Means and variations:

Number of records, actual means and standard deviations (**SD**) for pre-weaning litter traits in **B**, **CAL** and **NZW** rabbits are presented in Table 1. These means for all doe litter traits in **B**, **CAL** and **NZW** rabbits are generally within the range of those reported in the reviewed Egyptian studies. Means of all litter traits in **B** rabbits were slightly higher than those in **CAL** or **NZW** rabbits. This observation is in agreement with those of Farghaly (1996) for **LSB**, **LS21**, **LSW**, **LWB**, **LW21** and **LWW**. These results show also that **NZW** rabbits recorded slightly better values than **CAL** ones for all litter traits. This notation is similar to findings of many Egyptian studies for **LSB** (El-Maghawry *et al.*, 1988; El-Desoki, 1991; Khalil, 1993; Farghaly and El-Darawany, 1994); for **LS21** (Afifi *et al.* 1992; Farghaly and El-Darawany, 1994); for **LSW** at 28-30 days (El-sayiad *et al.*, 1993a; Farghaly and El-Darawany, 1994); for **LWB** (El-Maghawry *et al.*, 1988; Farghaly, 1996); for **LW21** (Yamani *et al.*, 1991); for **LWW** at 28-30 days (El-Desoki, 1991; Farghaly, 1996); for **MBWB** (El-Maghawry *et al.*, 1988; El-Maghawry, 1990); for **MBW21** (El-Maghawry, 1990); and for **MBWW** at 28 days (Oudah, 1990). However, the slight superiority of **NZW** rabbits over **CAL** ones for litter traits may be due to the superiority of **NZW** does in prenatal (ovulation rate, fetal survival, uterine capacity, intra-uterine environment, ...etc.) and postnatal (milk production, maternal behavior,

Table 1: Actual means, standard deviations (SD) and percentages of variation (V%) for doe litter traits in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits.

Traits	Symbol	Breed	No.	Mean	SD	V%
Litter size at birth	LSB	B	693	7.00	2.39	33.6
		CAL	207	6.71	2.33	34.3
		NZW	530	6.88	2.29	32.2
Litter size at 21 days	LS21	B	513	5.99	1.90	29.8
		CAL	134	5.57	2.10	35.2
		NZW	534	5.99	1.93	32.1
Litter size at weaning	LSW	B	423	5.85	1.80	29.6
		CAL	118	5.36	2.13	36.9
		NZW	297	5.76	1.76	30.7
Litter weight at birth (gm)	LWB	B	663	406	117	26.3
		CAL	199	366	111	28.7
		NZW	524	388	105	25.1
Litter weight at 21 days (gm)	LW21	B	511	1678	447	23.1
		CAL	132	1511	423	25.2
		NZW	350	1659	452	25.1
Litter weight at weaning (gm)	LWW	B	417	3248	971	26.9
		CAL	118	2690	1002	33.5
		NZW	293	3035	951	30.3
Mean bunny weight per litter at birth (gm)	MBWB	B	663	58.4	12.6	20.2
		CAL	199	55.6	9.8	17.5
		NZW	524	56.7	10.5	17.6
Mean bunny weight at 21 days (gm)	MBW21	B	511	299.3	81.1	26.8
		CAL	132	292.4	80.7	27.8
		NZW	352	293.7	76.4	26.0
Mean bunny weight at weaning (gm)	MBWW	B	417	577.1	128.0	21.2
		CAL	118	526.2	98.5	18.5
		NZW	293	542.9	119.3	21.3
Gain in litter weight up to 21 days (gm)	LG21	B	508	1263	383	27.2
		CAL	130	1133	362	29.1
		NZW	351	1256	394	29.8
Gain in litter weight up to weaning (gm)	LGW	B	417	2817	928	29.9
		CAL	116	2328	944	36.7
		NZW	293	2631	906	33.4

caring ability, ... etc.) maternal abilities as stated by Blasco *et al.* (1992) and Khalil (1993).

Percentages of variation (**V%**) for doe litter traits in B, **CAL** and **NZW** rabbits ranged from 29.6 to 36.9% for litter size traits, from 23.1 to 33.5% for litter weight traits, from 17.5 to 27.8% for mean bunny weight per litter traits and from 27.2 to 36.7% for gain in litter weight traits. These estimates are, in general, within the ranges found in the Egyptian studies (Afifi *et al.*, 1992; Abdel Raouf, 1993; Yamani *et al.*, 1994; Ahmed, 1997). The lower values of V% at birth than at weaning may be due to the differences in litter losses during the suckling period and in case of litter weight traits, they may be attributed to the increase in the differences in post-natal growth of the litter-mates up to weaning caused by differences in their genotypes and the variation in milk production of their dams during the suckling period (El-Maghawry, 1990; Afifi *et al.*, 1992; Khalil, 1994). Also, this is because litters between kindling and weaning become more sensitive to the non-genetic maternal effects (e.g. parity, age of doe, litter size at birth, ... etc.), which decreases thereafter with advance of litter's age (Khalil, 1993 & 1994).

The variability of litter size in B and **NZW** rabbits decreased from birth to weaning (Table 1). Percentages of variation of litter weight in **B** and **CAL** rabbits decreased from birth up to 21 days and increased thereafter. Yamani *et al.* (1994) with **CAL** rabbits detected similar trend for the same traits. Percentages of variation for mean bunny weight per litter increased from birth up to 21 days and decreased thereafter at weaning in the three breeds of this study. This trend is similar to that reported for the same trait by Ahmed (1997) in **CAL** and **NZW**. The increase in percentage of variation for mean bunny weight per litter from birth to 21 days and the decrease occurring thereafter till weaning may be attributed to that this trait has the same curvilinear pattern of milk production since milk yield reaching its peak at 21 days and decreased thereafter (Khalil, 1994).

Doe variance component:

Doe variance components (σ^2_d) and their percentages (V%) for litters of **B, NZW** and **CAL** rabbits estimated by **REML** method were low or moderate (Table 2). The percentages ranged from 2.2 to 19.9% for litter

Table 2. Doe (σ_d^2) and error (σ_e^2) variance components, their percentages (V%) and Repeatabilities (t) and their standard errors (S.E) estimated by REML method for litter traits in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits.

Trait+	Breed	Doe			Remainder			Repeatability
		df	σ_d^2	V%	df	σ_e^2	V%	t ± S.E
LSB	B	149	0.92	14.3	529	5.51	85.7	0.143 ± 0.032
	CAL	54	0.13	2.2	140	5.68	97.8	0.023 ± 0.010
	NZW	149	0.55	9.9	368	4.98	90.1	0.100 ± 0.030
LS21	B	141	0.79	19.9	357	3.17	80.1	0.200 ± 0.045
	CAL	38	0.28	6.7	83	3.90	93.3	0.068 ± 0.034
	NZW	110	0.41	9.9	231	3.73	90.1	0.099 ± 0.029
LSW	B	116	0.67	18.1	292	3.03	81.9	0.182 ± 0.046
	CAL	36	0.49	11.0	69	3.95	89.0	0.111 ± 0.056
	NZW	94	0.48	13.0	190	3.21	87.0	0.129 ± 0.040
LWB	B	149	3478.0	23.3	499	11451.1	76.7	0.233 ± 0.047
	CAL	54	4.4	3.5	132	121.7	96.5	0.035 ± 0.015
	NZW	148	19.0	16.4	363	97.0	83.6	0.164 ± 0.038
LW21	B	141	39158	20.9	355	148497	79.1	0.209 ± 0.046
	CAL	37	9337	6.1	82	144383	93.9	0.061 ± 0.031
	NZW	109	15511	8.0	230	178807	92.0	0.080 ± 0.024
LWW	B	115	139413	15.5	287	759160	84.5	0.155 ± 0.041
	CAL	36	25925	3.1	69	807407	96.9	0.031 ± 0.017
	NZW	93	96439	10.2	187	852541	89.8	0.102 ± 0.032
MBWB	B	149	0.15	9.1	499	1.49	90.9	0.090 ± 0.022
	CAL	54	0.05	4.8	132	1.00	95.2	0.048 ± 0.021
	NZW	148	0.02	1.8	363	1.09	98.2	0.022 ± 0.006
MBW21	B	141	1058	14.5	355	6257	85.5	0.145 ± 0.035
	CAL	37	3	0.0	82	6798	100.0	0.000 ± 0.001
	NZW	109	691	10.4	230	5961	89.6	0.104 ± 0.030
MBWW	B	115	6034	28.8	287	14894	71.2	0.171 ± 0.044
	CAL	36	4285	31.4	69	9379	68.6	0.314 ± 0.122
	NZW	93	1711	11.5	187	13223	88.5	0.115 ± 0.036
LG21	B	141	27125	19.0	352	115630	81.0	0.190 ± 0.043
	CAL	37	7113	6.1	80	108908	93.9	0.061 ± 0.032
	NZW	109	9308	6.2	229	139971	93.8	0.062 ± 0.019
LGW	B	115	118658	14.5	287	701052	85.5	0.145 ± 0.038
	NZW	93	79189	9.2	187	777448	90.8	0.092 ± 0.030

+ Traits are as defined in Table 1.

size traits; from 3.1 to 23.3% for litter weight traits; from 0.0 to 31.4% for traits of mean bunny weight per litter and from 6.1 to 19.0% for gain in litter weight up to weaning. Similarly, results of El-Raffa (1994) and Ahmed (1997) using the same **REML** method showed wide variation in percentages of doe variance component for litter traits. They reported ranges of 2.1 to 24.2% for litter size traits, 5.7 to 18.1% for litter weight traits, 13.1 to 39.4% for bunny weight per litter traits and 6.5 to 18.5% for gain in litter weight traits.

Percentages of doe component of variance ranged from 6.7 to 28.8% for **B** rabbits, 1.8 to 16.4% for **NZW** and 0.0 to 31.4% for **CAL** (Table 2). In general, estimates of doe variance component for each breed separately showed that **B** does were higher in variation than **CAL** and **NZW** does. At the same time, **CAL** does recorded the lowest estimates for all litter traits, except **MBWW** and **LG21**. The small values of doe variance component observed for most litter traits in **CAL** does may suggest that selecting does from dams with better litter traits would not assure genetic response unless corrections were made for maternal environment (Khalil and Afifi, 1991). Low variation in doe variance component of **CAL** does could be attributed to the small number of records used (sampling error). Such low estimates may also be due to the non-randomness in the distribution of the small numbers of does (daughters) within sire groups (Khalil and Afifi, 1991; Abdel-Raouf, 1993; Khalil, 1993). Under extensive system of production, Khalil and Afifi (1991) reported that the percentages of variation due to doe effects in litter traits of Giza White does were larger than the corresponding percentages of Bouscat does, i.e. higher variance of maternal and milking abilities from birth to weaning in Giza White does than in Bouscat ones. Khalil (1993) reported that percentages of doe component of variance for **NZW** and **CAL** rabbits raised extensively were lower than 20%, i.e. large environmental component of variance associated with the doe during kindling and raising her litters to weaning could be attained. Khalil (1994) stated that the genetic and environmental differences in pre- and post-natal maternal influences could be added as another causes in this respect.

Repeatability:

Repeatabilities estimated for doe litter traits (Table 2) indicate that doe litter traits were lowly or moderately repeatable. The estimates were higher in **B** rabbits than in **NZW** and **CAL** rabbits. Also, estimates for **NZW** rabbits were generally higher than for **CAL** ones. In fact, **CAL** breed is originated from **NZW** breed (as dam breed) and consequently a reduction in maternal variation was obtained. The results may be due to the variability in numbers of observations for each breed which were higher in **B** rabbits than in **NZW** ones and also higher in **NZW** rabbits than in **CAL** ones.

Low repeatability estimates for some litter traits in this study indicate that culling or selecting of does for these traits based on the first record is not useful. The low repeatability estimates reported by Ferraz *et al.* (1991b), Khalil and Afifi (1991) and Ayyat *et al.* (1995) indicate also that values of the first record (single record) are not good indicators for future performance and early records should not be used as a criteria for culling or selecting does. So, records on several parities may be helpful to cull or select future does as dams (Ferraze *et al.*, 1991b). Results of Lukefahr *et al.* (1984) in commercial herds of **NZW** and **CAL** rabbits showed that litter traits, were moderately to highly repeatable, except litter size at birth and at weaning along with litter weight at birth which were lowly repeatable. However, Afifi *et al.* (1992) reported that repeatability estimates for litter size and litter weight at birth were of moderate magnitude (0.15-0.23) and showed, in general, higher values at birth than at 21 days or at weaning. Khalil (1994) reported that estimates of repeatability for litter traits at 21 days (peak of lactation) and for lactation traits were higher than those for other litter traits, i.e. lactation traits are slightly more repeatable than litter traits.

Common litter effect:

Under intensive system of production, variance components attributed to the common litter effect (σ_c^2) and their percentages (**V%**) for doe litter traits are presented in Table 3. The percentages were low or moderate and ranged from 4.8 to 13.5% for litter size traits, from 2.5 to 17.8 for litter weight traits, from 6.6 to 22.7% for mean bunny weight per litter traits and from 5.7 to 11.7% for gain in litter weight up to weaning. **CAL** rabbits recorded the lowest estimates for most litter traits when compared to **B** and **NZW** rabbits. The percentages were higher in **B** rabbits than in **CAL** and **NZW** for **LS21, LSW, LWB, LW21** and **LG21**; while they were higher in **NZW** rabbits than **B** and **CAL** for **LSB, LWW, MBW21** and **LGW**.

Similar to that found in σ_d^2, across all traits, percentages of σ_c^2 averaged 10.9% in **B**, 10.4% in **NZW** and 8.2% in **CAL**, i.e. dam of

Table 3. Variance components of common litter effect (σ_c^2) and their percentages (V%) estimated for litter traits in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits.

Trait+	Breed	Common litter effect			Remainder		
		df	σ_c^2	V%	Df	σ_e^2	V%
LSB	B	119	0.7	10.9	59	5.7	90.1
	CAL	45	0.4	6.9	149	5.4	93.1
	NZW	119	0.7	12.5	398	4.9	87.5
LS21	B	113	0.5	12.8	385	3.4	87.2
	CAL	33	0.2	4.8	88	4.0	95.2
	NZW	91	0.4	9.8	250	3.7	90.2
LSW	B	92	0.5	13.5	316	3.2	96.5
	CAL	31	0.4	9.1	74	4.0	90.9
	NZW	75	0.4	10.8	209	3.3	89.2
LWB	B	166	2644	17.8	532	12202	82.2
	CAL	45	1085	8.6	141	11527	91.4
	NZW	166	1624	14.0	395	9937	86.0
LW21	B	133	23365	12.4	383	164914	87.6
	CAL	32	8921	5.8	87	144799	94.2
	NZW	90	14751	7.6	249	179473	92.4
LWW	B	91	87762	9.8	311	809269	90.2
	CAL	31	21235	2.5	74	812432	97.5
	NZW	74	110952	11.7	206	837199	88.3
MBWB	B	116	11.1	7.0	532	147.0	93.0
	CAL	45	7.2	7.2	141	92.5	92.8
	NZW	116	7.5	7.1	395	97.7	92.9
MBW21	B	113	486	6.6	383	6863	93.4
	NZW	90	851	12.8	249	5784	87.2
MBWW	B	91	1686	9.4	311	16313	90.6
	CAL	31	3059	22.7	74	10415	77.3
	NZW	74	1679	11.2	206	13285	88.8
LG21	B	113	16819	11.7	380	126612	88.3
	CAL	32	7311	6.3	85	108678	93.7
	NZW	90	8568	5.7	248	140709	94.3
LGW	B	91	71983	8.8	311	746853	91.2
	NZW	74	95190	11.1	206	761159	88.9

+ Traits are as defined in Table 1.

doe and parity in which doe was born had considerable effects on litter traits of **B** and **NZW** rabbits.

Doe breeding values (DBV):

Breeding values of litter traits for all does with records were estimated by single-trait Animal Model (AM). The **BLUP** estimates obtained for litter traits by taking into account the common litter effect as well as the relationship coefficient matrix among does (A^{-1}). For single-trait Animal Model, the number of iterations recorded for the evaluation of doe litter traits in **NZW**, **CAL** and **B** rabbits are presented in Table 4. For **B** does, the number of iterations averaged 114 iterations for litter size traits, 168 iterations for litter weight traits, 129 iterations for mean bunny weight per litter traits and 128 iterations for gain in litter weight traits (Table 4). The corresponding figures recorded for **CAL** and **NZW** respectively averaged 120 and 118, 234 and 137,127 and 86 and 102 and 126 iterations in the same order. For most cases, these results indicate that data of **NZW** and **B** does required less iterations to reach adequate convergence criteria

Table 4. Numbers of iterations recorded by single-trait Animal Model (AM) for doe litter traits in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits.

Trait+	B	CAL	NZW
LSB	115	133	127
LS21	105	115	109
LSW	122	111	119
LWB	128	145	160
LW21	96	135	134
LWW	280	143	117
MBWB	118	144	18
MBW21	111	119	107
MBWW	158	119	133
LG21	110	102	107
LGW	145	B	146

+ Traits are as defined in Table 1.

b = Data was not analyzed because estimate of intraclass correlation was negative.

compared to **CAL** does. Ducroco *et al.* (1990) and Wiggans and Van Raden (1990) reported that number of rounds of iteration required to reach the same convergence rate (used as stopping point and adequate convergence criteria) may not be met before 100 or more iterations.

For does of intensive production used here, the minimum and the maximum estimates of breeding values for all does with records (i.e. **BLUP**) in addition to their ranges (i.e. the difference between the maximum and minimum values) are presented in Table 5. In general, ranges of breeding values estimated for all does gave an evidence that **B** rabbits surpassed those of the other two breeds in **DBV** and those of **NZW** rabbits are higher than those of **CAL** ones. These results may be due to that **B** rabbits recorded the highest genetic variability followed in a descending order by **NZW** and **CAL** rabbits. Thus, improvement of these traits might be more effective in **B** rabbits than in the other two breeds.

Ranges in **DBV** for litter size traits of all **B** does (Table 5) reveal that these ranges decreased with advance of age of the litter. In **CAL** rabbits, these ranges increased with advance of age of the litter from birth up to weaning. In **NZW** rabbits, these ranges decreased, in general, from birth up to 21 days and increased thereafter up to weaning. For litter weight-traits, **DBV** increased with advance of age of the litter from birth up to weaning in the three breeds. The same trend was observed for gain in litter weight traits in **B** and **NZW** rabbits. For mean bunny weight per litter traits (Table 5), **DBV** were found to increase with advance of age of the litter from birth up to weaning in **B** and **NZW** rabbits, while they were found to decrease from birth up to 21 days and increased thereafter up to weaning in **CAL** rabbits. In general, ranges in estimates of **DBV** of all does increased with advance of age of the litter. This may be due to that the expression of the genotype is more clear at weaning than at earlier ages. Thus, selection for a composite trait at weaning (e.g. **LWW**) might be more effective to improve many traits than selection for a simple trait at birth or at weaning.

The numbers and percentages of does with positive breeding values estimated for litter traits (Table 6) indicate, in general, that does having positive estimates of breeding values were less than 50% of all does in the three breeds. Across the three breeds, the percentages of does having positive breeding values averaged 49.44% for litter size traits, 49.38% for

Table 5. Minimum, maximum and ranges of doe breeding values (DBV) estimated by single-trait Animal Model (AM) for litter traits in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits raised under commercial intensive system of production.

Trait+	Doe breeding values											
	B				CAL				NZW			
	No. of records	Minimum	Maximum	Range	No. of records	Minimum	Maximum	Range	No. of records	Minimum	Maximum	Range
LSB	150	-1.31	1.08	2.39	55	-0.19	0.16	0.35	150	-0.72	0.74	1.46
LS21	142	-1.21	0.95	2.16	39	-0.28	0.37	0.65	111	-0.51	0.55	1.06
LSW	117	-0.95	0.86	1.81	37	-0.44	0.58	1.02	95	-0.63	0.65	1.28
LWB	150	-85.3	59.3	144.6	55	-12.9	10.3	23.2	149	-63.8	66.7	130.5
LW21	142	-252.1	260.9	513.0	38	-68.1	54.1	122.2	110	-97.4	76.9	174.3
LWW	116	-385.7	494.3	880.0	37	-77.8	86.0	163.8	94	-210.2	315.7	525.9
MBWB	150	-3.0	6.5	9.5	55	-0.8	2.0	2.8	149	-0.6	0.7	1.3
MBW21	142	-32.5	51.5	84.0	38	-0.1	0.1	0.2	110	-13.2	31.9	45.1
MBWW	116	-61.9	76.2	138.1	37	-59.1	84.6	143.7	94	-30.9	46.2	77.1
LG21	142	-222.9	209.7	432.6	38	-46.1	42.3	88.4	110	-71.3	62.2	133.5
LGW	116	-356.1	448.5	804.6		b	b	B	94	-170.8	280.5	451.3

+ Traits are as defined in Table 1.

b = Estimates of DBV were not predicted because estimate of doe intracalass correlation was negative.

Table 6. Numbers and percentages of does having positive estimates of breeding values (DBV) as well as their percentages (%) recorded by single trait Animal Model (AM) in Bouscat (B), Californian (CAL) and New Zealand White (NZW) rabbits raised under commercial intensive system of production.

Trait +	B		CAL		NZW	
	No. of does	% of does	No. of does	% of does	No. of does	% of does
LSB	79	52.7	27	49.1	70	46.1
LS21	69	48.6	21	53.8	56	50.5
LSW	57	48.7	19	51.4	45	47.4
LWB	78	52.0	24	50.1	70	47.0
LW21	78	45.2	24	63.2	57	51.8
LWW	45	46.6	16	43.2	48	51.1
MBWB	68	45.3	22	40.0	64	43.0
MBW21	66	46.5	18	47.4	46	41.8
MBWW	53	45.7	21	56.8	37	39.4
LG21	74	52.1	21	55.3	57	51.8
LGW	52	44.8	b	b	49	52.1

+ Traits are as defined in Table 1.

b = Data was not analyzed because estimate of intraclass correlation was negative.

litter weight traits, 44.33% for mean bunny weight per litter traits and 50.6% for gain in litter weight traits.

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