

**GENETIC AND PHENOTYPIC ANALYSIS
FOR SOME REPRODUCTIVE TRAITS IN RABBITS**

BY

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Introduction

In recent year, genetic evaluation of rabbits was most often performed using Animal Model which requires good estimates of variance components (*Ferraz et al, 1991&1992; Baselga et al, 1992a; Reverter et al. 1994; Hassan, 1995*). For obtaining variance component estimates, the preferable estimation methods of variance components have been prohibitively expensive from a computational standpoint for routine application to field data having unequal numbers of observation per subclass, even with assumed homogeneity of genetic and residual variances. With balanced data, there is an evidence that confirm the fact that Restricted Maximum Likelihood (**REML**) produces the same estimators as Analysis of Variance (**ANOVA**) methods (*Corbeil and Searle, 1976; Anderson et al. 1984*). The **ANOVA** estimators have well known optimal properties in these circumstances. For unbalanced data and for very non-linear equations, REML is preferred to solve these equations iteratively. Other interest in REML, centered around estimation of variances and covariances from records subjected to selection (*Rothschild et al., 1979*). *Thompson (1979) and Searle (1989)* suggested that REML could be used to remove bias from selection.

Most research in methodology of rabbit breeding and evaluation has been undertaken in developed countries (e.g. in France, USA, Spain, Italy,etc.). In these countries, methodology has been applied to large data sets, more or less balanced and connected, and containing full genealogy. However, the situation in many developing countries is really far from such type of data sets. Thus, the efficiency of some methods of estimating variance components should be tested before introducing more expensive techniques which could be unnecessary.

The objectives of the present study were: (1) to estimate variance components and sire heritabilities for some litter traits and reproductive intervals using Henderson's method and Restricted Maximum Likelihood (REML), in New Zealand White (NZW) and Californian (CAL) rabbits raised in Egypt and (2) to compare between the estimators obtained from the two methods.

3. MATERIAL AND METHODS

The experimental work of this study was carried out in an investment company of rabbits in Ismailia governorate, Egypt. It lasted for three consecutive years started in 1987.

3.1 Animals and Breeding Plan

Two foreign breeds of New Zealand White (NZW) and Californian (CAL) rabbits were used in this study. At the beginning of the breeding season, females within each breed were grouped at random into groups ranging from 6 to 7 does depending upon the available numbers. For each group of does, a buck from the same breed was assigned at random with the restriction of avoiding full-sib and half-sib and parent-offspring matings. All over the period of the study each buck was allowed to produce all his litters from the same assigned females. This mating design leads to produce several progenies for each successful sire-dam combination.

3.2. Rabbitry and Management

Breeding females and males were housed separately in individual-wired cages of flat-deck type. Cages were arranged in a windowless insulated rabbitry. Cage of each doe was provided with a metal nest box for kindling and nursing her progeny during the suckling period. Cages and nest boxes were cleaned and disinfected regularly before each kindling. Every day in the morning, urine and faces dropped from cages were cleaned by scraper.

According to the breeding plan of the experiment, each doe was transferred to the buck's hutch to be bred. Hand mating was exercised and each doe was weighted at each mating and palpated 10 days thereafter to determine pregnancy. Does that failed to conceive were returned to the same mating buck to be rebred and were returned to the same buck every other day thereafter until a service was observed. On the 25th day of pregnancy, the nest boxes were supplied with wood dust to provide a comfortable and warm nest for the young rabbits. After kindling, new born litters were examined and their size and weight were recorded within 24 hours. Bunnies were weaned four weeks after birth. At weaning, size and weight of litters were recorded and the young rabbits were separated from their dams and housed in wired hutches in Californian type (60x30x35 cm). Rabbits of nearly similar age (with a maximum number of 4 individuals) were housed in one hutch. Young doe replacements were added to the herd weekly throughout the course of the study.

Rabbits were always fed *ad-libitum* and food was offered two times daily. A commercial pelleted ration was provided in the morning and in the afternoon. The composition of that ration was 18% crude protein, 13% crude fiber and 3% fat (digestible energy= 2800 Kcal/1kg ration). The ingredients of this ration were 35% hay, 12% wheat bran, 22% soya bean meal (44% crude protein), 15% yellow corn, 10% barely, 3% molasses, 1.3% table salt, 0.5%

minerals and vitamins, 0.15% methionine and 1.5% lime stone. Fresh clean water was available to rabbits at all times.

3.3 Data

Data utilized in this study were collected on 361 does for NZW and 332 does for CAL. The distribution of records collected according to breed and year of kindling is presented in **Table (12)**.

Litter traits at birth included litter size (LSB), number born alive (NBA), number born dead (NBD), litter weight (LWB), while litter traits at weaning included litter size (LSW), litter weight (LWW), average weight per litter (AWW) and number dead before weaning (NDW). Number of services per conception (NSC) and some reproductive intervals such as days open (period from kindling to next conception, DO) and kindling interval (days between two successive litters, KI) were also investigated in the present study.

3.4. Statistical Analysis

3.4.1 Models of analysis

Data of NZW and CAL breeds were analyzed separately using Mixed Model Least-squares and Maximum Likelihood Mean Weighted Program of Harvey (**Harvey, 1990**). Data of litter traits (at birth and at weaning) and reproductive intervals of each parity were analyzed using the following mixed model:

$$Y_{ijk} = \mu + s_i + ys_j + e_{ijk}$$

where Y_{ijk} = the observation on the ijk^{th} litter, μ = overall mean, s_i = random effect of i^{th} sire, ys_j = fixed effect of j^{th} year-season of kindling and e_{ijk} = random deviation of k^{th} litter of i^{th} sire and assumed to be independently randomly distributed $(0, \sigma_e^2)$.

3.4.2 Estimation of variance components

3.4.2.1 Henderson's III method:

(i) Theory

Estimation of variance components for litter traits and reproductive intervals were computed according to Harvey's LSMLMW (**Harvey, 1990**) using Henderson's method 3 (**Henderson, 1984**). The basic procedure of Henderson method 3 can be briefly described in the following steps:

Step 1: Start with the following mixed model

$$\begin{matrix} X'X & X'Z & f & X'Y \\ & & = & \\ Z'X & Z'Z & s & Z'Y \end{matrix} \dots\dots\dots (1)$$

where f=represent all fixed effects (year-season subclasses in model 1), s= represent the random effect (sire effect) in the model and X= represents known incidence matrix for fixed effects, and Z= represents known incidence matrix for random effect of sire.

Step 2: Solve equation (1) to get the estimates for the unknown f and s:

$$\begin{matrix} f & X'X & X'Z^{-1} & X'Y \\ = & & & \\ s & Z'X & Z'Z & Z'Y \end{matrix} \dots\dots\dots (2)$$

Step 3: Compute the reduction due to full model R(f,s) as:

$$R(f,s) = \begin{bmatrix} f & s \end{bmatrix} \begin{bmatrix} X'Y \\ Z'Y \end{bmatrix} = fX'Y + sZ'Y \dots\dots\dots (3)$$

Step 4: Compute the reduction due to the fixed effect only R(f) as:

$$R(f) = \begin{bmatrix} f \end{bmatrix} \begin{bmatrix} X'Y \end{bmatrix} \dots\dots\dots (4)$$

$$\text{where } f = \begin{bmatrix} X'Y \end{bmatrix}^{-1} \begin{bmatrix} X'Y \end{bmatrix} \dots\dots\dots (5)$$

Step 5: Compute the variance components estimates as:

(i) The error component of variance (σ^2_e) was estimated as:

$$\sigma^2_e = [Y'Y - R(f,s)] / df \text{ error} \dots\dots\dots (6)$$

(ii) The sire component (σ^2_s) of variance can be estimated by equating:

$$R(s) = R(f,s) - R(f) \dots\dots\dots (7)$$

to its expectation and solving to estimate the sire component of variance (σ^2_s).

(ii) Analysis of variance (ANOVA)

The analysis of variance table (ANOVA) for reproductive intervals and litter traits (at birth and at weaning) for results of the previous steps are given in **Table 13**.

Table (13) . Analysis of variance (ANOVA) for mixed model used.

Source of variation	df	Sum squares	EMS
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Sire	s-1	$R(\mu, f, s) - R(\mu, f)$	$\sigma_e^2 + k_1 \sigma_s^2$
Fixed	f-1	$B'Z B$ (adjusted for sire effect)	$\sigma_e^2 + kK_f^2$
Remainder	$N-(s+f-1)$	$Y'Y - R(\mu, f, s)$	σ_e^2

where R = the reduction in sum of squares obtained by maximum likelihood procedure; s = number of sires, N = total number of observations, f = levels of each fixed effect in the model, k_1 = weighing coefficient of sire component of variance, and σ_s^2 = variance component of sire. By equating mean squares of random effects to their expectations, estimates of variance components for sire (σ_s^2) and remainder (σ_e^2) were obtained.

3.4.2.2. REML method

(i) Theory

Variance component estimation using REML was proposed by **Petterson and Thompson (1971)**. This method is an iterative method and the random effects are estimated appropriately. Iterations are continued using the estimators of sire and error variances from the preceding round of iteration until the estimates are stabilized.

(ii) Difference between Henderson's method and REML

Computational differences in estimating the variance components for sire and error with the above two methods are as follows:

Let, $Z'MZ$ = coefficient matrix for sires after absorbing all fixed effects and covariables,

$Z'My$ = vector of sire totals of the dependent variable after absorbing all fixed effects and covariable,

$(Z'MZ)$ = generalized inverse of $Z'MZ$ matrix,

σ_e^2 = estimated error variance,

σ_s^2 = estimated sire variance,

N = total number of observations,

q = number of sires,

X = designed matrix for fixed effects and covariables,

Z = designed matrix for sires (random),

$M = R - R X(X'R X)^{-1} X'R$

tr = trace,

S = estimate of sire effect with Henderson's method III,

S^* = estimate of sire effect with REML

Then the estimators from Henderson's method III:

$S = (Z'MZ)^{-1} Z'My$

$\sigma_e^2 = [y'My - s'(Z'My)] / [N - \text{rank}(X, Z)]$

$s = [S'Z'My] - e(q-1) / \text{tr}(Z'MZ)$

The estimators from REML:

$$\begin{aligned}s^* &= [Z'MZ + I(\sigma_e^2/\sigma_s^2)] Z'My \\ e &= [y'My - s^*(Z'My)] / [N - \text{rank}(x)] \\ s &= [s^*s^* + e^2 \text{tr}(Z'MZ + I(\sigma_e^2/\sigma_s^2))] / 9\end{aligned}$$

The quantity, $I(\sigma_e^2/\sigma_s^2)$ is the “identity matrix multiplied by the ratio of error to sire variance”. In the first round of iteration a guessed value of the ratio is used (like the estimates of Henderson’s method), and then a value based on the estimates of sire and error variances from the preceding round is used.

3.4.3 Estimation of heritability

Heritability (h_s^2) was estimated for reproductive intervals and litter traits as $4(\sigma_s^2)/(\sigma_s^2 + \sigma_e^2)$. Standard error of the h_s^2 estimated by Henderson method was calculated according to formula given by **Swiger et al. (1964)**. The approximate standard error for h^2 estimated using REML was calculated by the formula given by **Becker (1984)** as follows:

$$SE = 4\sqrt{2(1-t)^2 [1+(k-1)t]^2 / k(k-1)(s-1)}$$

where SE= standard error, t= intraclass correlation, k= k value of sire weighing factor (**Table 14**) and s= number of sires.

4. RESULTS AND DISCUSSION

4.1 Means of uncorrected records

4.1.1 Litter Traits

Means, standard deviations and percentages of variation for litter traits in each separate parity for New Zealand White (NZW) and Californian (CAL) rabbits are presented in **Table 15**. Litter traits changed but with no definite pattern with advance of parity (**Table 15**). Means for litter traits in different parities show that the highest performance was generally recorded by litters of the second and third parities when compared with litters of other parities. NBA, LSW and LWW in both breeds were increased from the first parity to the second parity and decreased thereafter up to 9th parity, while NBD, NDW and

AWW were generally decreased from the first parity to the third parity and increased thereafter. In other words, the performance of the first two parities was the best for LSB, NBA whereas LSW of the second and third parities were the best. However, the number dead either at birth or at weaning was maximum in the first parity and in later ones (i.e. from six parity and later).

In most parities, the performance of litter traits at birth in NZW was slightly higher than those of CAL breed (**Table 15**). NBA and NDW for both breeds are nearly similar in different parities (**Table 15**). AWW for NZW is larger than that for CAL breed (**Table 15**). The reviewed estimates reported in different Egyptian studies (**El-Maghawry et al., 1988; Askar, 1989; Abdella et al., 1990; El-Desoki, 1991; Sedki, 1991; Yamani et al., 1991; Youssef, 1992; Khalil, 1993b**) indicated that performance of litter traits in NZW rabbits are better than those in CAL. The present and reviewed results were expected and reflecting the superiority of NZW does in their prenatal (in terms of ovulation rate, ova wastage, embryo survival, fetal survival, uterine capacity, intra-uterine environment,... etc) and postnatal (in terms of milk production, maternal behavior, caring ability, ... etc) maternal abilities than CAL does (**Hulot and Matheron, 1980; Lukefahr et al., 1983b; Blasco et al., 1992**). Better performance in NZW does than in CAL was also declared by many other non-Egyptian investigators. In this concern, **Ponce de Leon (1978), Rouvier (1980) and Masoero et al. (1985)** in Europe have been reported that using NZW as a doe breed produced high performance in litter size traits compared to other doe breeds.

Means of litter traits (LSB, NBA, NBD, LSW, LWW, AWW) reported here and those reviewed from literature for NZW and CAL rabbits indicated that rabbits of these two standard breeds raised in other Mediterranean countries are relatively better than those rabbits raised in Egypt. Accordingly, the genetic potentiality of these two standard breeds raised in adverse environment are not completely expressed in Egypt. This is due to NZW and CAL rabbits were raised in Egypt under unsuitable climatic and management conditions. Reduction due to the existence of genotype-environment interaction could be added as another cause in this respect.

4.1.2 Reproductive performance

Means and their standard deviation (SD) and percentages of variation (V%) of doe reproductive performance in separate parities for NZW and CAL rabbits are presented in **Table 16**.

For separate parities, it is clear that different parities have similar NSC, DO and KI (**Table 16**). **El-Desoki (1991)** obtained moderate means of 22.8 and 20.9 days for DO in NZW and CAL raised in Egypt. **Abd El- Raouf (1993)**

found that DO for NZW and CAL ranged from 10.4 to 12.7 days. The same author found that KI for both breeds ranged from 51.4 to 52.4 day. Most of the Egyptian studies (i.e. **Khalil and Mansour, 1987, El-Desoki, 1991, Hilmy, 1991; Sedki, 1991; Youssef, 1992**) indicated also that pattern of interval traits (DO&KI) in different parities was inconsistent.

Reproductive intervals for NZW rabbits were relatively lower than those in CAL rabbits (**Table 16**). Periods of DO and KI obtained here indicated also that these intervals are moderate in both breeds raised in adverse environment (DO and KI averaged 16.1 and 31.6 days for NZW and 17.5 and 47.3 days for CAL, respectively). These moderate intervals are one of the encouraging factors to use these exotic breeds in Egypt on a large scale of commercial production. **El-Desoki (1991)** confirmed this concern since he obtained moderate means of DO and KI for NZW and CAL rabbits raised under the Egyptian conditions. The estimates for DO and KI were 22.8 and 52.6 days in NZW and 22.8 and 51.4 days for CAL rabbits, respectively. Also, **Khalil (1993a&b)** reported that the estimates for DO and KI were 17.9 and 48.8 days for Giza White rabbits (GW), 10.4 and 42.2 days for NZW and 12.7 and 43.7 days for CAL rabbits.

4.2 Variations of uncorrected records

4.2.1 Litter traits

The percentages of phenotypic variation (V%) for uncorrected litter traits in NZW and CAL rabbits are presented in **Table 15**. These estimates were found to be changed, with no clear pattern, as age of litter advanced in both breeds. In general, estimates of V% for LSW were greater than those for LSB in each parity. Similarly, **Lukefahr (1982), Khalil et al. (1987b), Afifi et al. (1992), Hassan (1995), Khalil (1993a) and Abd El-Raouf (1993)** observed higher V% at weaning than at birth for litter traits. Higher percentage of variation in litter size at weaning than at birth may be due to differences in litter losses during the suckling period and to differences in post-natal growth of the litter-mates up to weaning caused by differences in their genotypes and in milk production of their dams during the suckling period (**Khalil, 1994**). High variability of litter traits at birth and at weaning would lead to a greater improvement in these traits through phenotypic selection at weaning than at earlier ages. In the reverse direction, higher variability for NBD than that for NDW may lead to state that a higher improvement in this trait will be gained at earlier ages than at weaning. The estimates of V% given in **Table 15** indicated that phenotypic variation in litter traits was high in the first parity and decreased thereafter until the fourth one which increased forward with advance of parity. **Hulot and Matheron (1980) and Blasco et al. (1992)** attributed the high

variation in litter traits at birth to the high variation in ovulation rate, embryo and fetal survival and uterine capacity.

Variations of all uncorrected litter traits in NZW and CAL rabbits were generally moderate or high (**Table 15**). Results of **Lukefahr (1982)**, **Khalil et al. (1987b)**, **El-Maghawry (1990)**, **Lukefahr et al. (1990)** and **Khalil (1993a)** confirmed this concept. **Khalil et al. (1987a)** and **Khalil (1994)** attributed this concept on the basis of great variation in growth of bunnies (in terms of variation in milk production) along with preweaning survival where the bunnies up to the age of 12 day (when they open their eyes) remained solely on their dam's milk and thereafter the dam's milk provided the main supply of nutrients for the young until they were weaned. It may be also due to that litters after kindling until weaning become more sensitive to the non-genetic maternal effects (e.g. parity, age of doe, ... etc.) which decrease thereafter with advancing of litter's age.

In each separate parity, estimates of V% in NZW rabbits ranged from 18.5 to 25.5% for LSB, from 17.9 to 32.5% for NBA, from 65.5 to 96.0% for NDW, from 17.6 to 35.8% for LSW, from 16.2 to 34.3% for LWW and from 7.0 to 15.1% for AWW (**Table 15**). For CAL rabbits, the corresponding estimates were from 15.5 to 23.7%, 17.0 to 38.7%, 81.3 to 137.0%, 17.0 to 39.0%, 6.9 to 37.0% and 6.4 to 13.2% (**Table 15**). Figures for both breeds in each separate parity showed that AWW recorded the lowest variation while NDW recorded the highest variation. LSB, NBA, LSW and LWW recorded moderate variation (**Table 15**). High or moderate variation obtained here for most litter traits in NZW and CAL rabbits and those high estimates observed by other Egyptian studies for the same traits of the same two breeds and/or other breeds gave an evidence that improvement of litter traits in rabbits through phenotypic selection is quite possible (**Khalil et al., 1987a&b; El-Maghawry, 1990; Hilmy, 1991; Abd El-Raouf, 1993; Khalil, 1993b; Khalil, 1994**).

4.2.2. Reproductive Performance

Estimates of V% in **Table 16** showed that phenotypic variations of uncorrected interval traits (DO and KI) and NSC were moderate or high in different parities. The estimates ranged from 14.2 to 61.7% in different parities. These estimates indicated that KI exhibited the lowest phenotypic variation while DO and NSC showed the largest variability. Variability trend in different parities of both breeds did not show any consistent trend (**Table 16**).

Variation in DO in both breeds was relatively high compared with KI (**Table 16**). This trend is clear since estimates of V% for DO ranged from 46.0 to 60.7% in NZW and from 40.9 to 57.6% in CAL, while they ranged from 15.6 to 18.8% for KI in NZW and from 14.2 to 18.4% in CAL. The corresponding

estimates reported by another Egyptian study (**Khalil, 1993b**) were 138 and 56% for DO and KI in NZW, while they were 122 and 36% for CAL rabbits, respectively. However, high variation in reproductive intervals of doe rabbits in Egypt could be attributed to the variation in management decisions (in terms of post-partum mating system, remating schedule, ... etc.).

4.3 ANOVA and tests of significance

ANOVA and F-ratios estimated by Henderson method and REML along with tests of significance of factors contributing to the variation of different doe traits in NZW and CAL rabbits are shown in **Tables 17&18&19&20&21&22**. In most cases, year-season affected significantly litter traits at birth and at weaning in both breeds, while it showed insignificant effect on DO, KI and NSC in most parities of both breeds.

Least-squares means for litter traits (LSB, NBA, NBD, LSW, LWW, NDW and AWW) and reproductive performance traits (NSC, DO and KI) in different year-season subclasses are presented in **Appendices 1&2&3&4&5&6**.

4.4 Variance components

For both breeds, differences in most doe traits due to sire effect were inconsistent and not significant (**Tables 17&18&19**). In Egypt, some investigators reported non-significant sire effect on litter traits in rabbits (**Khalil et al., 1987b; Afifi et al., 1989; Farghaly et al., 1993**), while others reported significant effect (**Khalil et al., 1987a; Khalil and Afifi, 1991; Khalil, 1993a; Farghaly et al., 1993**). **Afifi et al. (1992)** with NZW and CAL rabbits found that sire affected significantly LSW in NZW ($P < 0.05$), while it had no significant effect on all other doe traits (LSB, LS21, LWB, LW21 and LWW). **Khalil (1993a)** with Giza White (GW) rabbits reported insignificant sire effect for all traits studied (LSB, LSW, LWB and LWW) except PM ($P < 0.001$).

Ronningen (1972) reported that the knowledge of variance components and the size of heritability is of great importance in the decision of which selection methods should be used. **Khalil et al. (1986)** reported that the apparent differences in sire variance components and heritabilities for litter traits in rabbits were probably due to: (i) the method of estimation, (ii) the genetic make-up of the breeds in the herd, (iii) the available number of observations used in the estimation, and (iv) the correction for the non-genetic factors which were made on each set of data.

4.4.1 Methods of estimation and variance components

The variance components estimated using Henderson's method and Restricted Maximum Likelihood (**REML**) along with percentages of variation (V%) attributed to the sire and remainder for litter traits, number of services per

conception and reproductive intervals in NZW and CAL rabbits are shown in **Tables 23&24&25&26**.

In different parities, percentages of variation due to sire estimated here using **Henderson** method were low or somewhat moderate (**Tables 23&25**). The estimates for CAL rabbits ranged from 0.1 to 7.1% for LSB, 1.1 to 2.4% for NBA, 0.8 to 1.5% for NBD, 0.3 to 5.0% for NDW, 0.6 to 6.0% for LSW, 1.8 to 6.7% for LWW, 0.01 to 9.3% for AWW, 0.2 to 3.9% for NSC, 1.1 to 3.4% for DO and 0.8 to 3.4% for KI. The corresponding estimates in NZW ranged from 0.8 to 10.9% for LSB, 0.6 to 4.0% for NBA, 1.4 to 10.0% for NBD, 1.6 to 11.2% for NDW, 0.04 to 2.2% for LSW, 0.2 to 1.4% for LWW, 0.4 to 10.9% for AWW, 0.1 to 2.4% for NSC, 0.5 to 5.1% for DO and 0.2 to 4.3% for KI. In Egypt, most estimates of sire variance components were detected using Henderson method. In NZW, the reviewed estimates of sire variance component were 1.9% for LSB, 2.7% for LSW, 2.4% for LWB and 0.9 for LWW, while they were 2.9, 1.8 and 2.2% for LSB, LSW and LWB in CAL, respectively (**Afifi et al., 1989; Afifi et al., 1992**).

As for Henderson method, low or relatively moderate estimates of sire variance component were obtained using **REML** for litter traits and reproductive intervals in different parities (**Tables 24&26**). The estimates for CAL rabbits ranged from 6.4% for LSB, 1.2 to 2.9% for NBA, 0.5 to 4.4% for NBD, 0.2 to 4.9% for NDW, 0.01 to 5.8% for LSW, 1.9 to 6.5% for LWW, 0.7 to 9.6% for AWW, 1.8 to 4.2% for NSC, 0.2 to 2.3% for DO and 0.6 to 3.1% for KI. The corresponding estimates in NZW ranged from 3.2 to 10.4% for LSB, 0.8 to 6.1% for NBA, 2.3 to 5.8% for NBD, 1.9 to 5.0% for NDW, 0.3 to 1.9% for LSW, 0.4 to 1.3% for LWW and 0.7 to 11.7% for AWW, 0.2 to 1.5% for NSC, 3.8 to 4.0% for DO and 0.1 to 3.1% for KI. In Egypt, scarce estimates of variance attributed to sire components were found. The reviewed estimates almost were negative in NZW (**Hassan et al, 1994**). **El-Raffa (1994)** with NZW found that estimates of sire component of variance were 2.5, 1.7 and 2.1% for LSB, NBA and LSW.

Reviewed percentages of variation estimated by **Henderson** or **REML** methods show that the contribution of sire was generally low or moderate and ranged from 1.3 to 6.1% for LSB, 1.8 to 6.6% for LSW, 1.5 to 10.0% for LWB and 0.9 to 20.0% for LWW (**Khalil et al, 1987a; Khalil and Afifi, 1991; Afifi et al., 1992; Khalil et al., 1993a**). Such low or moderate percentages of variation in litter traits may be due to that system of feeding and management practices might have masked the full expression of non-genetic paternal differences of sire.

For litter traits in NZW and CAL rabbits, estimates of sire component of variance obtained using **REML** method are generally smaller than those obtained using **Henderson** method (**Tables 23&24**), i.e. error variances for **REML** method were larger than those for **Henderson** method. **Teepker and Swalve (1988), Cameron (1988), Raheja (1992) and Xu et al, (1994)** reported that the sire variance components obtained using **Henderson** method were smaller than those estimated using **REML** procedure.

For NSC, DO and KI in both breeds of the present study, sire component of variance estimated using REML or Henderson methods showed that no definite trend could be plotted along the parity (**Tables 25&26**). **Khalil (1993a)** came to the same conclusion for the same two breeds of rabbits.

4.4.2 Genetic make-up of the breeds and variance components

For litter traits of both breeds, most estimates of sire component of variance (V%) obtained using Henderson or REML methods were lower than 12% (**Tables 23&24**), reflecting the large environmental components of variance associated with the sire (**Khalil et al., 1987a**). For each separate parity, percentages of variance (V%) attributed to sire effect for litter traits of NZW rabbits were generally larger than those estimates obtained for CAL rabbits (**Tables 23&24**). A reverse trend was observed for reproductive intervals (e.g. DO and KI) where CAL rabbits recorded the highest estimates of sire component of variance (**Tables 25&26**). High variation in paternity of lactation of NZW rabbits may be responsible for such high estimates of V% for litter traits in this breed, while stress of lactation in such breed may be the cause of low V% due to sire for reproductive intervals. Since CAL rabbits originated from NZW rabbits and an intensive selection programme was practiced in the establishment of CAL, therefore, a reduction in V% due to sire could be attained for litter traits in this breed. The reviewed estimates of variance components due to sire for litter traits and reproductive intervals are quite variable between NZW and CAL raised in Egypt (**Afifi et al, 1989; Afifi et al, 1992; Khalil, 1993a; Farghaly et al, 1994**).

4.5. Heritabilities

Sire heritabilities estimated using **Henderson** and **REML** methods for litter traits, number of services per conception and reproductive intervals in NZW and CAL rabbits are given in **Tables 23&24&25&26**. However, sire heritabilities in the present study were similar to those obtained by some Egyptian investigators (**Khalil et al., 1987a, Afifi et al., 1992, Khalil, 1993b; Farghaly et al., 1994**). Other non-Egyptian studies on different breeds showed low sire heritabilities for litter traits in rabbits (**Garcia et al., 1980, Randi and Scossiroli, 1980, Lahiri and Mahajan, 1982, Panella et al., 1992, Ferraz et**

al., 1992; Baselga et al., 1992a). The discrepancy between most estimates obtained in this study and the corresponding estimates reported in the literature may be attributed to the different breeds of rabbits reared under particular environmental conditions during definite periods of time. Statistically, the wide range can be attributed to the use of small data sets with poor structure and to a variety of statistical methods used.

4.5.1 Method of estimation and heritabilities

Sire heritabilities estimated using **Henderson** method for litter traits and reproductive intervals in NZW and CAL rabbits were low or relatively moderate (**Tables 23&25**). These heritabilities for different parities ranged from 0.004 to 0.284 for LSB, 0.043 to 0.095 for NBA, 0.031 to 0.059 for NBD, 0.018 to 0.120 for NDW, 0.022 to 0.24 for LSW, 0.072 to 0.269 for LWW, 0.001 to 0.372 for AWW, 0.051 to 0.177 for NSC, 0.042 to 0.120 for DO and 0.034 to 0.135 for KI in CAL rabbits, while they ranged from 0.032 to 0.437 for LSB, 0.023 to 0.161 for NBA, 0.058 to 0.40 for NBD, 0.046 to 0.146 for NDW, 0.002 to 0.087 for LSW, 0.007 to 0.055 for LWW, 0.003 to 0.435 for AWW, 0.005 to 0.096 for NSC, 0.022 to 0.205 for DO and 0.007 to 0.174 for KI in NZW rabbits. The reviewed h^2 estimated using Henderson method for litter traits in NZW raised in Egypt were also low. These estimates in NZW were 0.08, 0.13, 0.10, and 0.05 for LSB, LSW, LWB and LWW, respectively (**Afifi et al., 1992; Farghaly et al., 1994**), whereas the corresponding estimates in CAL rabbits were 0.11, 0.07, 0.09 and 0.28 for LSB, LSW, LWB and LWW (**Afifi et al., 1992**).

As in Henderson method, sire heritabilities estimated using REML for litter traits and reproductive intervals in NZW and CAL rabbits were low or relatively moderate (**Tables 24&26**). These estimates in different parities ranged from 0.0 to 0.022 for LSB, 0.048 to 0.257 for NBA, 0.019 to 0.093 for NBD, 0.009 to 0.197 for NDW, 0.011 to 0.179 for LSW, 0.074 to 0.233 for LWW, 0.013 to 0.26 for AWW, 0.070 to 0.166 for NSC, 0.052 to 0.108 for DO and 0.022 to 0.093 for KI in CAL rabbits, while they ranged from 0.126 to 0.416 for LSB, 0.030 to 0.245 for NBA, 0.092 to 0.232 for NBD, 0.076 to 0.20 for NDW, 0.060 to 0.075 for LSW, 0.016 to 0.050 for LWW, 0.028 to 0.467 for AWW, 0.006 to 0.058 for NSC, 0.151 to 0.158 for DO and 0.005 to 0.123 for KI in NZW rabbits. The corresponding reviewed estimates obtained using **REML** for NZW and CAL rabbits raised in Egypt were scarce. The available estimates reported by **El-Raffa (1994)** were 0.10, 0.69 and 0.084 for LSB, NBA and LSW in NZW rabbits. In Mediterranean countries, the corresponding estimates in NZW and CAL were 0.054 for LSB and 0.074 for LSW (**Baselga et al., 1992a**). In USA, sire heritabilities for NZW and CAL rabbits were low or relatively moderate and ranged from 0.054 to 0.212 for LSB, 0.063 to 0.299 for

NBA, 0.0 to 0.138 for LSW, 0.043 to 0.071 for LWB, 0.0 to 0.21 for LWW and 0.002 to 0.023 for preweaning mortality rate (**Ferraz et al., 1991&1992**).

Reviewed negative and low heritability estimates and those obtained here using **Henderson** or **REML** may be due to the large maternal variation that could mask any additive genetic variance due to increasing non-additive genetic effect (**Garcia et al., 1982a**). In general, estimates of heritability for litter traits computed by **REML** are lower than those estimates obtained by **Henderson** method. Comparing reviewed heritabilities estimated using **Henderson** method for litter traits in rabbits (**Garcia et al., 1980; Randi and Scossiroli, 1980; Khalil et al, 1987a; Afifi et al, 1992; Farghaly et al., 1994**) with those heritabilities estimated using **REML** method (**Baselga et al., 1992a; Ferraz et al., 1991&1992; El-Raffa, 1994; Hassan, 1995**), it is clear that estimates of **REML** method are somewhat lower than those estimates obtained by **Henderson** method. In this respect and for rabbits, methods like **MIVQUE** or **REML** have been recommended (**Baselga et al., 1992a; Ferraz et al., 1992; El-Raffa, 1994; Hassan, 1995**). In species other than rabbits, **Chauhan (1991)** reported that heritability estimated using **Henderson**, estimate for milk yield in cattle decreased from 0.41 to 0.24 estimated using **REML** procedure. Also, **Gama et al. (1991)** obtained unexpected higher heritability estimates from **Henderson** method than those estimated by **REML** procedure. The same authors explained these discrepancies to the difference in the two data set that were used in the two methods. **Raheja (1992)** found that the heritabilities estimated using **Henderson** method were overestimated by about 15-20% than those calculated using **REML**. Simulation studies (e.g. **Rothschild et al., 1979; Meyer and Thompson, 1984; Sorensen and Kennedy, 1984**) have shown that customary methods like **Henderson** method, lead to biased estimates when selected data are used. In contrast to above mentioned trend, **Cameron (1988)** with sheep, **See et al. (1993)** with swine, **Swalve et al. (1992)** with dairy cattle reported that heritabilities estimated using **Henderson** method were slightly smaller than those estimated by **REML** procedure.

The extremely small differences (0.02) between heritability estimated using **Henderson** method and **REML** were also observed in other studies (**Colleau et al., 1989; Schutz et al., 1990; Ahlborn and Dempfle, 1992**). The explanation may be due to that a comparatively balanced design and an efficient data structure from progeny testing sires in contracted herds were used. These systematic matings generated a homogenous number of daughters per sire and a sufficient number of sires providing connections between cells. **Reverter et al. (1994)** noted that **REML** procedure produces the same estimators as **ANOVA** methods with balanced data (**Corbeil and Searle, 1976; Anderson et al., 1984**).

4.5.2 Available number of records and heritabilities

Small or negative estimates of most sire heritabilities obtained here and large standard errors of positive estimates could be attributed: (1) to the small sample size per generation (**Narayan et al., 1985**), (2) to the small number of progeny per sire (**El-Maghawry, 1990**), (3) to the non-randomness in the distribution of daughters within sire groups (**Khalil, 1989**), and (4) to the sampling error (**Thompson and Moor, 1963**).

4.5.3 Genetic make-up of breeds and heritabilities

Although all estimates of heritability are generally low, estimates for all litter traits in NZW rabbits are higher than those corresponding estimates in CAL rabbits, while the reverse was observed for reproductive interavals (**Table 25**). This reverse notation is clear since heritability estimates ranged from 0.05 to 0.177 for NSC, 0.009 to 0.108 for DO, 0.022 to 0.125 for KI in CAL rabbits, while they ranged from 0.006 to 0.058 for NSC, 0.151 to 0.158 for DO and 0.005 to 0.123 for KI in NZW rabbits. In Egypt , a fluctuated trend for reviewed h^2 estimated using Henderson method was observed. In this respect, **Afifi et al. (1992)** and **Farghaly et al. (1994)** found that h^2 estimated for LSB and LWW were greater in CAL (0.11 and 0.28) than that in NZW (0.08 and 0.05), while the reverse trend was observed for LSW (0.07 vs 0.13) and LWB (0.09 vs 0.10).

Summary

The present field data were collected from an investment company of rabbits in Ismailia governorate for three years (1987, 1988 and 1989). Two exotic breeds of New Zealand White (NZW) and Californian (CAL) raised under the Egyptian commercial conditions were included in the investigation. Data on 4702 litters was used to evaluate genetically some litter traits and

reproductive intervals for these two breeds. The traits investigated were litter size at birth (**LSB**), number born alive (**NBA**), number born dead (**NBD**), litter size at weaning (**LSW**), number dead at weaning (**NDW**), litter weight at weaning (**LWW**) and average bunny weight at weaning (**AWW**), while reproductive traits included number of services till conception (**NSC**), days open (**DO**) and kindling interval (**KI**). Variance components and sire heritabilities within breed and parity were estimated for these traits using **Henderson** method and **Restricted Maximum Likelihood (REML)**. A comparison between estimators obtained from the two methods was attempted. A linear mixed models were used for analyzing such data. The results obtained could be summarized as:

(i) Litter traits

The performance of litter traits within parity for **NZW** and **CAL** rabbits did not show any definite pattern. The performance of the first two parities was the best for litter size at birth and number born alive, whereas litter size at weaning of the second and third parities were the best. The number dead either at birth or at weaning was maximum in the first parity and in later ones (from six and later parities). The performance of **NZW** does at birth and at weaning was slightly higher than those of **CAL** does with values of 8.4 vs 7.8, 7.4 vs 6.8, 1.95 vs 1.45, 5.6 vs 5.7, 2983 vs 2868 and 534 vs 512 for **LSB**, **NBA**, **NBD**, **NDW**, **LSW**, **LWW** and **AWW**, respectively. For both breeds, the percentages of phenotypic variation (**V%**) for litter traits were generally high and ranged from 15.5 to 38.7% at birth and from 6.9 to 137% at weaning. Litter traits at birth and at weaning were not significantly affected by sire of doe, whereas they were significantly affected by year-season effect.

(ii) Reproductive traits

Reproductive performance within parity for both breeds did not show any clear pattern. The averages were 1.6 for **NSC**, 18.8 day for **DO** and 48.9 day for **KI**. The reproductive performance of **NZW** does were generally better than those of **CAL** does with averages of 18.1 vs 19.5 days for **DO** and 47.9 vs 49.9 days for **KI**. The percentages of phenotypic variation (**V%**) for reproductive traits were high and ranged from 16.3 to 53.9%. The phenotypic variability of reproductive traits in **NZW** rabbits were generally higher than those in **CAL** rabbits. These estimates were 40.9 vs 38.9% for **NSC**, 53.9 vs 46.5% for **DO** and 17.2 vs 16.3% for **KI** in **NZW** and **CAL** rabbits, respectively. Reproductive

traits were not significantly affected by sire of doe and also most of these traits were not significantly affected by year-season effect.

(iii) Additive genetic variance

The sire of doe has inconsistent effect on litter traits and reproductive intervals in different parities. For both breeds, estimates of sire variance component within parity were low and ranged from 3.6 to 6.8% for **LSB**, 1.8 to 3.5% for **NBA**, 1.2 to 5.7% for **NBD**, 2.6 to 6.4% for **NDW**, 1.1 to 3.3% for **LSW**, 0.8 to 4.3% for **LWW** and 4.7 to 6.2% for **AWW**. The estimates for reproductive performance were also low and ranged from 0.9 to 3.0% for **NSC**, 1.3 to 3.9% for **DO** and 1.6 to 2.3% for **KI**.

The additive genetic variance for litter traits and reproductive intervals obtained from using **Henderson** method in **NZW** rabbits were generally higher than those in **CAL** rabbits in almost traits. The estimates were 5.9% vs 3.6% for **LSB**, 2.3% vs 1.8% for **NBA**, 5.7% vs 1.2% for **NBA**, 6.4% vs 2.7% for **NDW**, 5.7% vs 4.7% for **AWW**, 2.8% vs 2.3% for **DO** and 2.3% vs 2.1% for **KI**. The same notations were also observed when using **REML** procedure.

Sire variance components resulted from **REML** procedure had larger estimators in 50% of the traits than those obtained using **Henderson** method. The two procedures gave nearly the same estimates in 20% of the traits, while there was unexpected increase in estimates of **Henderson** than in **REML** by only 30% of the traits.

(iv) Heritability

For both breeds, sire heritabilities (h^2) estimated using **Henderson's** method within parity ranged from 0.011 to 0.235 for **LSB**, 0.069 to 0.153 for **NBA**, 0.056 to 0.31 for **NBA**, 0.069 to 0.138 for **NDW**, 0.045 to 0.131 for **LSW**, 0.031 to 0.258 for **LWW**, 0.137 to 0.248 for **AWW**, 0.032 to 0.140 for **NSC**, 0.08 to 0.155 for **DO** and 0.058 to 0.091 for **KI**.

The sire heritabilities estimated using **Henderson** method within parity for litter traits in **NZW** rabbits were generally larger than those in **CAL** rabbits in almost traits. The estimates were 0.235 vs 0.144 for **LSB**, 0.092 vs 0.069 for **NBA**, 0.096 vs 0.069 for **NDW**, 0.219 vs 0.187 for **AWW**, 0.114 vs 0.081 for **DO** and 0.091 vs 0.085 for **KI**. The same trend was also observed for h^2 estimated using **REML** method.

Comparing h^2 estimated using **Henderson's** method with **REML** procedure, estimates show that **REML** had larger estimates than those for **Henderson** method in 45% of the traits. The two procedures gave nearly the same estimates in 5%, while there was unexpected increase in estimates of **Henderson** than in **REML** by 50% of the traits.

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