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SIRE AND DAM TRANSMITTING ABILITIES FOR LITTER SIZE TRAITS IN THREE LINES OF RABBITS RAISED IN HIGH INTENSIVE SYSTEM OF PRODUCTION

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Data on 3804 litters of 3 lines of rabbits (N, Z and G) coming from 1301 does, the daughters of 335 sires and 815 dams were analyzed to study the effect of non-genetic factors (year and season of kindling, parity, litter interval and number born alive previous) on litter size traits. Evaluation of sires and dams by estimating transmitting abilities (i.e. estimation of BLUP) from actual production records of intensive reproduction system was the main goal of this study. Line N was the highest in litter size. Season of kindling and litter interval constituted the most important non-genetic factors influencing litter size traits. Across all lines studied, variations of uncorrected litter size traits were high and ranged from 30.3 to 63.7 %.

Estimates of sire variance and heritability of litter size traits using REML with sires relationship coefficient matrix (A^{-1}) were generally low in all lines and ranged from 2.2 to 5.3 %. Transmitting abilities estimated for dams were somewhat higher than those estimated for sires. For all lines, BLUP for dams ranged from 1.5 to 4.3 young, while BLUP estimates for sires ranged from 0.9 to 2.0 young, i.e. selection based on dams performance may be effective to improve litter size in rabbits than that based on records of sires.

Key words : Rabbits, iitter size, heritabilities, sire and dam transmitting abilities.

Litter size is a very important trait in rabbit production. Current genetic schemes for rabbit meat production are based on a three way cross, two lines of which are selected for litter size in order to produce the crossbred doe and the other line is selected for growth rate in order to produce terminal sires (Blasco, 1996). Evidence in the literature (Khalil *et al.,* 1987; El-Zanfaly, shortly after parturition, which implies weaning at four weeks (Lange and Schlolaut, 1988). In addition, Szendro (1989) concluded that reducing the remating interval after parturition could be considered as a stress factor by which animals standing out in intensive utilization, and those with the best constitution could be selected for increased kindling frequency. Cervera *et al.* (1993) concluded that does mated intensively (1 to 2 days after post parturition) were less fertile when reared large litters, but the final result was a higher number of weaned rabbit per year.

The knowledge of variance components and the size of heritability is of a great importance in the decision of which selection methods should be used. The recent papers (Baselga *et al.*, 1992; Ferraz and Eler, 1994; Rochambeau *et al.*, 1994 and Gomez *et al.*, 1996) have utilized animal models in genetic analysis of litter traits in rabbits. Best linear unbiased predictors (BLUP), under methodology of mixed models is becoming the preferred method for animal breeders to evaluate their animals (Henderson, 1988). Restricted maximum likelihood (REML) of variance or covariance component is also becoming the most commonly algorithm used in such estimations. Procedure of best linear unbiased predictor (BLUP) developed by Henderson (1972), was used throughout the world for sire and dam evaluations. In rabbit breeding, selection of sires and dams for litter size based on this method could be effective in this respect.

The objectives of the present study were : (1) to analyze the effects of year and season of kindling, parity, litter interval and number born alive previous as covariate on litter size in three lines of rabbits raised under high intensive system of production, i.e. 10 litters per doe per annum, (2) to estimate variance components and heritability for these litter size traits using restricted maximum likelihood (REML) considering relationship among sires and (3) to estimate the sire and dam transmitting ability for these traits produced under such stress-system of production.

MATERIALS AND METHODS

Data on 3 lines of rabbits (N, Z and G) were collected on 3804 litters coming from 1301 does, the daughters of 335 sires and 815 dams, between 1993 and 1995 at the nucleus breeding farm of ZIKA (Schweizerhof, Untergröningen, Germany). Line N was originated from New Zealand White breed. Line Z was produced by mating various local German strains, while line G was developed from Giant breed. All these lines were selected for productive ability. An account of these lines was reported by El-Raffa (1994).

Under high intensive system of production, the breeding schedule allowed for a maximum of 10 litters produced per doe per annum. The doe was inseminated within the first few days after kindling using artificial insemination with previously prepared fresh semen taken from a buck selected randomly from the breeding group. All inseminations were made at random with the only restriction pertaining to close relatives. Does were palpated 18 days post insemination to detect pregnancy. Those failed to conceive were reinseminated at the next insemination date which was repeated every 33 days for the same doe group. Does which were not pregnant 3 times consecutively were eliminated. At the 33rd day pregnancy, the birth was released by an injection of oxytocin in case of the doe had not littered until then. During the preweaning period, unrestricted food and water was allowed. Litters were weaned at the mean age of 28 days. Young does were added to the herd as needed to replace those lost by death and culling. The housing and feeding for these lines were reported by El-Raffa *et al.* (1997). Litter size born alive (only animals that survived the first 12 hours after delivery) and litter size at birth and at weaning were the traits under study.

Data on litter size traits were analyzed separately for each line using restricted maximum likelihood (REML) procedure taking into account sires relationship coefficient matrix (A^{-1}); (Harvey, 1990). In this method, REML was used for estimating variance components. In this case, the mixed-model equations were used to obtain BLUP of the random effects, best linear unbiased estimators (BLUE) of the fixed effects and minimum normal quadratic unbiased estimators (MINQUE) of the variance components. The sire mixed model in matrix notation was:

$$y = X\beta + Zs + e$$

where y is the vector of observations, X and Z are known incidence matrices for fixed and random effects, respectively, β is unknown column vector of fixed effects (year and season of kindling, parity, litter interval and number born alive previous as covariate), s is unknown column vector of random effects of sires, and e is a column vector of random error. Litter interval is defined as the number of days between two successive (under study - former) kindlings of the same doe (1st level = 28-38 days, 2nd level = 39-71 days and 3rd level = $\geq$ 72 days). The first litter has not been taken into consideration to be able to find out the influence of the preceding litter interval. Number born alive previous is the number of kits born alive in the former kindling. The mixed model equations (MME) for such sire model were :

$$\begin{vmatrix} Z'X & Z'Z + kA^{-1} \end{vmatrix} \begin{vmatrix} \hat{s} \end{vmatrix} \quad \begin{vmatrix} Z'y \end{vmatrix}$$

where $k = \sigma^2_e/\sigma^2_s$ estimated by REML procedure and A^{-1} = the inverse of the relationship matrix among sires. The minimum variance normal quadratic unbiased estimates (MINQUE) of sires (σ^2_s) and error (σ^2_e) variance components as described by Henderson (1984) were calculated using LSMLMW program of Harvey (Harvey, 1990). Sire transmitting abilities were calculated using best linear unbiased predictor (BLUP) taking into account sires relationship coefficient matrix (A^{-1}).

Since, MIXMDL program of Harvey's (1990), which computes estimates of variance components, limits the number of random effects to 150 for a set of cross-classified or nested random effects when REML with relationship matrix is used, and the number of dams used in the present study exceeded 150 in each line, dam transmitting ability was determined using BLUP without dams relationship coefficient matrix (A^{-1}). One set of cross-classified non-interacting random effects (dam) was absorbed (Harvey, 1990). Accordingly, BLUP estimates for random dam effects absorbed by maximum likelihood were obtained. The following model (in matrix notation) was used.

$$y = X\beta + Zd + e$$

where d is unknown column vector of random effects of dams, and all other symbols were previously described. Representing this model by matrix notation could be as follows :

$$\begin{vmatrix} X'X & X'Z \\ Z'X & Z'Z + Ik \end{vmatrix} \begin{vmatrix} \hat{\beta} \\ \hat{d} \end{vmatrix} = \begin{vmatrix} X'y \\ Z'y \end{vmatrix}$$

where I = Identity matrix, $k = \sigma^2_e/\sigma^2_d$ and solution to d, was called BLUP predictor of d.

Heritability estimates were obtained from sire component of variance. Standard errors for the heritability were calculated approximately by the formula given by Becker (1984). Mean separation test for fixed effects was performed by the method of Duncan (1955).

RESULTS AND DISCUSSION

Means and variations:

All traits were abbreviated and symbols are given in Table 1. Means, standard deviations and percentages of variation of litter size in N, Z and G lines of rabbits are presented in this table. Line N was the highest in litter size. In contrast, line G was the lowest. In this concern, Masoero *et al.* (1985) reported that using New Zealand White rabbits as a doe breed, produced high performance in litter size traits compared to other doe breeds. Variations of all uncorrected litter size traits in all lines were generally moderate or high (Table 1). The estimates ranged from 30.3 to 63.7 % across all lines. Results of Khalil *et al.* (1987), Lukefahr *et al.* (1990) and El-Zanfaly (1996) confirmed this concept. Khalil *et al.* (1987) 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 days (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

Table1. Actual means, standard deviations (SD) and percentages of variation (CV %) of litter size traits in the three lines under study.

Line	Trait	Abbre-viation	No.	Mean	SD	CV %
N	Litter size born alive	LSBA	1850	8.1	3.1	37.3
	Litter size at birth	LSB	1850	8.6	3.1	34.6
	Litter size at weaning	LSW	1850	6.6	2.0	30.3
Z	Litter size born alive	LSBA	1285	7.6	2.6	33.6
	Litter size at birth	LSB	1285	8.1	2.6	30.3
	Litter size at weaning	LSW	1285	6.6	2.1	30.3
G	Litter size born alive	LSBA	669	7.1	3.3	44.4
	Litter size at birth	LSB	669	8.0	2.9	35.9
	Litter size at weaning	LSW	669	3.8	2.5	63.7

capacity. However, the differences in litter size reported by different author: might be in principle attributed to differences in breed group, feeding management, climatic conditions, diseases and number of records available fo the estimation (El-Raffa, 1994).

Non-genetic effects :

Year and season of kindling:

Year of kindling had no effect on litter size traits in all lines (Table 2) Litter size at birth (LSB) was significantly affected by season of kindling in al lines, while litter size at weaning (LSW) was affected by year in line N only. I could be concluded that LSW was less affected by season than LSB Moreover, LSB and LSW were the lowest in summer (Table 2). Litter siz born alive (LSBA) was the highest in spring for line N and Z (8.6 and 8.3 respectively), but it was not influenced by season in line G. Season-of kindling differences in litter size are usually associated with differences i climatic conditions. In this respect, Gomez *et al.* (1996) reported tha magnitude of seasonal effects was high.

Parity:

Except for LSW of line N, parity effects constituted an insignifican source of variation in litter size for all lines (Table 2). Afifi and Khalil (1990 reported that litter size decreased insignificantly with advance of parity However, the pattern of change in litter size due to parity effects may be result of changes in physiological efficiency of the doe which occurs wit advance in parity, especially those related to ovulation, implantation an prenatal survival rates and due to differences in the intra-uterine environmen during gestation length (Afifi and Khalil, 1990).

Litter interval:

Litter size traits (LSBA, LSB and LSW) were significantly influenced b litter intervals for all lines with the exception of LSB in line G. For lines Z an G, the shortest litter interval (28-38 d) leads to a reduction in litter size trait in comparison to the highest litter intervals (Table 2). Such reduction in litte size in the shortest litter interval may be due to that suckling of young durin pregnancy may have an antagonistic effect on this trait. Similar results wer reported by Maertens *et al.* (1988) and El-Raffa (1994) who indicate

Table 2. Least-squares means (LSM), standard errors (SE) and test of significance of factors affecting litter size traits in the three lines.

Classi-fication	Line N							Line Z							Line G						
		LSBA		LSB		LSW			LSBA		LSB		LSW			LSBA		LSB		LSW	
	No.	LSM	SE	LSM	SE	LSM	SE	No.	LSM	SE	LSM	SE	LSM	SE	No.	LSM	SE	LSM	SE	LSM	SE
Overall mean	1850	8.4	.1	8.8	.1	6.6	.0	1285	7.8	.1	8.2	.1	6.8	.1	669	7.3	.2	8.0	.2	4.0	.1
Kindling year																					
1993	474	8.4	.2	8.8	.2	6.6	.1	324	7.9	.2	8.3	.2	6.8	.1	204	7.6	.3	8.4	.3	4.1	.2
1994	703	8.4	.1	8.8	.1	6.6	.1	425	7.8	.1	8.3	.1	6.8	.1	252	7.2	.3	7.9	.3	4.1	.2
1995	673	8.3	.1	8.7	.1	6.5	.1	536	7.7	.1	8.2	.1	6.8	.1	213	7.1	.3	7.8	.2	3.9	.2
Kindling season		**		***		**			**		***							**			
Winter	343	8.6^{a}	.2	8.9^{a}	.2	6.7^{a}	.1	312	7.8^{b}	.2	8.2^{b}	.2	6.8	.1	148	7.7	.3	8.7^{a}	.3	3.9	.2
Spring	288	8.6^{a}	.2	9.2^{a}	.2	6.6^{a}	.1	335	8.3^{a}	.1	8.6^{a}	.1	7.0	.1	207	7.5	.3	8.4^{a}	.3	4.2	.2
Summer	597	7.9^{b}	.1	8.2^{b}	.1	6.4^{b}	.1	312	7.7^{b}	.1	8.4^{ab}	.1	6.7	.1	160	6.9	.3	7.5^{b}	.3	3.9	.2
Autumn	622	8.4^{a}	.1	8.8^{a}	.1	6.7^{a}	.1	326	7.5^{b}	.1	7.8^{c}	.1	6.7	.1	154	7.2	.3	7.6^{b}	.3	4.0	.2
Parity						***															
2	568	8.3	.1	8.8	.1	7.0	.1	510	7.7	.1	8.1	.1	6.8	.1	234	7.6	.2	8.2	.2	4.3	.2
3	432	8.5	.1	8.9	.1	6.9	.1	312	8.0	.1	8.5	.1	6.9	.1	147	7.5	.3	8.2	.3	4.2	.2
4	316	8.4	.2	8.8	.2	6.6	.1	209	7.8	.2	8.5	.2	6.9	.1	108	7.4	.3	8.1	.3	4.2	.2
5	226	8.2	.2	8.7	.2	6.4	.1	140	8.1	.2	8.5	.2	6.9	.1	75	7.1	.4	7.9	.3	3.7	.3
6	156	8.5	.2	8.8	.2	6.5	.1	68	7.5	.3	7.9	.3	6.4	.2	47	7.3	.5	7.8	.4	4.2	.3
≥7	152	8.2	.2	8.6	.2	6.2	.1	46	7.8	.4	8.1	.3	6.9	.3	58	7.1	.4	7.9	.4	3.6	.3
Litter interval		***		***		***			***		***		***			**				***	
28-38 d	1358	7.9^{b}	.1	8.4^{b}	.1	6.4^{b}	.0	829	7.3^{b}	.1	7.8^{b}	.1	6.4^{b}	.1	457	6.6^{b}	.2	7.7	.1	3.4^{b}	.1
39-71 d	410	9.1^{a}	.1	9.6^{a}	.1	6.9^{a}	.1	374	8.1^{a}	.1	8.6^{a}	.1	6.9^{a}	.1	182	7.5^{a}	.2	8.3	.2	4.3^{a}	.2
≥ 72 d	82	8.0^{b}	.3	8.3^{b}	.3	6.5^{b}	.2	82	8.1^{a}	.3	8.3^{a}	.2	7.1^{a}	.2	30	7.9^{a}	.6	8.1	.5	4.4^{a}	.4
b[1]		.04	.0	.02	.0	.02	.0		.01	.0	.002	.0	-.003	.0		.03	.0	.01	.0	.04	.0

[1] Linear regression coefficient of litter size on number born alive previous.

** P ≤ .01 *** P ≤ .001

Means within columns for each factor with different superscript are significantly different (P < .05).

that there was a general tendency for litter size to be smaller when the inter
between successive parturition decreased.

For line N, the litter intervals of 28-38 and ≥ 72 days were statistica equal in all litter size traits, but they were significantly lower than intermediate litter interval (39-71 d). The litter interval of 39-71 days was, general, the highest in litter size. As expected, the lower litter size obtained the intensive reproduction system is usually coupled with an increase number of litters per doe (Cervera et al., 1993). Therefore, intens reproduction system is not recommended in intensive production system.

Number born alive previous:

The insignificant estimates of linear regression coefficients of litter s traits on the number born alive previous (Table 2) revealed that litter sizes the current delivery were independent from the number of kits born alive in previous litter.

Variance components and heritabilities:

The estimates of sire and error components of variance for litter size shown in Table 3. These estimates were quite variable among N, Z and lines. The percentages of the variance attributable to the sire component LSBA and LSB (4.3 and 4.4 %, respectively) of line Z were intermed between the corresponding variances of line N (both were 2.2 %), and lin (4.7 and 5.3 %). Therefore, line N was the lowest and line G was the high One explanation may be that line G has only a short history of selection. the other hand, the contribution of sire for LSW in line Z was higher than other two lines (Table 3). El-Raffa (1994) reported that estimates of components of variance were 1.7, 2.5 and 2.1 % for LSBA, LSB and LSW New Zealand White rabbits.

REML heritability estimates for litter size traits (LSBA, LSB and LS were low in all lines with the exception of LSB in line G (Table 3). Th heritability estimates of litter size were within the range of those reported the literature (Baselga *et al.*, 1992; Krogmeier *et al.*, 1994; Gomez *et al.*, 19 and Wu Zhan-Fu *et al.*, 1996). On the other hand, high heritability values litter size were obtained by Khalil *et al.* (1989), Blasco *et al.* (1993) Krogmeier *et al.* (1994). The reason of low heritability for litter size may due to the large maternal variation that could mask any additive gen variance due to increasing non-additive genetic effect (Garcia *et al.*, 1982).

Table 3. Variance components (σ^2) and heritabilities (h^2_s) for litter size traits estimated by restricted maximum likelihood (REML with relationship of sires considered) in the three lines.

Traits	Line N			Line Z			Line G		
	σ^2_s	σ^2_e	h^2_s ± SE	σ^2_s	σ^2_e	h^2_s ± SE	^2_s	σ^2_e	h^2_s ± SE
LSBA	.21 (2.2)	9.21 (97.8)	.09 ± .04	.29 (4.3)	6.46 (95.7)	.17 ± .07	.49 (4.7)	9.99 (95.3)	.19 ± .11
LSB	.20 (2.2)	8.81 (97.8)	.09 ± .04	28 (4.4)	6.02 (95.6)	18 ± .07	47 (5.3)	8.37 (94.7)	21 ± .11
LSW	12 (2.9)	3.99 (97.1)	.12 ± .05	.14 (3.4)	4.03 (96.6)	13 ± .06	.18 (2.9)	6.00 (97.1)	.12 ± .10

σ^2_s, σ^2_e are the sire and error variances.
h^2_s is the h^2 estimated from sire component.
Figures given within brackets are the percentages of variance components.

Sire and dam evaluation:

Sire transmitting ability estimates (STA) were obtained by the procedure of BLUP considering relationship coefficient matrix among sires (A^{-1}) for litter size traits in the three lines (Table 4). Considering all sires in line N, there were differences between the minimum and maximum values of STA, being 1.08, 1.11 and .93 for LSBA, LSB and LSW traits, respectively. The mean difference estimates of STA for line N were lower than those of line Z, while line G had the highest STA values (Table 4). Considering the top sires for line N, Z and G, it was noticed that the differences between the maximum and minimum in STA were smaller than that when considering all sires. Estimates of STA for LSW were lower than those for LSBA and LSB in all lines. Across all lines, the mean negative percentage estimates of STA were 49.2, 50.7 and 49.1 % for LSBA, LSB and LSW, respectively.

The minimum and maximum estimates of dam transmitting ability (DTA) estimates by BLUP procedure for litter size in N, Z and G lines are presented in Table 5. The differences between minimum and maximum values of DTA in line N, were 3.34, 3.02 and 2.38 for LSBA, LSB and LSW, respectively. Dams of line N were intermediate in their transmitting ability of litter size between the lowest line (line G) and the highest one (line Z). Moreover, DTA estimates for LSW were lower than those for LSBA and LSB in all lines. Among all dams, the lowest percentage of dams having negative estimates of DTA was LSW in all lines (Table 5).

Table 4. Minimum and maximum values for sire transmitting ability for litter size traits estimated by best linear unbiased predictor (BLUP considering relationship coefficient matrix of sires, A^{-1}) in the three lines.

	Traits	All sires[1]				Top
					%	
N	LSBA	-.57	.51	1.08	46.9	.4
	LSB	-.61	.50	1.11	49.6	.4
	LSW	-.54	.39	.93	47.8	.3
Z	LSBA	-.77	.92	1.69	52.6	.8
	LSB	-.90	.87	1.77	51.8	.7
	LSW	-.54	.40	.94	48.9	.3
G	LSBA	-.82	.99	1.81	48.2	.8
	LSB	-1.23	.84	2.07	50.6	.7
	LSW	-.61	.44	1.05	50.6	.3

[1]Numbers of sires used for evaluation were 113, 137 and 85 sires for line N, Z and G, respectively.

[2]Top sires, which represent the selected ratio, was approximately 30 % of all sires.

Table 5. Minimum and maximum values and negative estimares (%) for dam transmitting ability estimated by best linear unbiased predictor (BLUP) for litter size traits in the three lines.

Line	Trait	Min.	Max.	Range	Negative estimates %
N	LSBA	-1.85	1.49	3.34	47.7
	LSB	-1.74	1.28	3.02	50.1
	LSW	-1.50	0.88	2.38	44.9
Z	LSBA	-1.69	2.60	4.29	50.2
	LSB	-1.45	2.23	3.68	49.8
	LSW	-0.96	0.85	1.81	46.8
G	LSBA	-0.81	1.22	2.03	51.6
	LSB	-1.04	1.19	2.23	54.9
	LSW	-0.78	0.74	1.52	45.8

Number of dams evaluated were 363, 299 and 153 for N, Z and G lines, respectively.

CONCLUSION :

(1) Tests of significance of all factors and covariates included in the model of analysis indicated that season of kindling and litter interval constituted the most important factors influencing litter size traits.

(2) The estimates of sire variance obtained in the present study using REML with sires relationship coefficient matrix (A^{-1}) for litter size traits were generally low in all lines, i.e. the contribution of sires was low.

(3) From results obtained here, it could be concluded that the environmental error was the main factor that affect litter size. So, there is no enough evident to use the individual selection to improve litter size in rabbits. The methods of family, within family and combined selection can improve litter size. In addition, selection for the traits related to litter size (i.e. milk production and ovulation rate) could be effective to improve this trait.

(4) It was noticed that sire and dam evaluations have been used extensively in dairy, beef and swine breeding work, but little in rabbits.

(5) The large differences in estimates of sire and dam transmitting ability obtained in the present study can introduce the possibility of making the correct culling decision and selecting the best sires and dams from those having positive estimates of transmitting ability for litter size. Due to the advantages to use artificial insemination (Facchin, 1992), and frozen embryos techniques in rabbits (Vicente and Garcia, 1993 a and b), sire and dam evaluations for litter size should be used in rabbits, mainly to reduce the cost, to increase the productive does and to spread the interesting genetic characteristics into future breeding.

REFERENCES

Afifi, E. A. and Khalil, M. H. (1990). Observations on purebred and crossbred litters of Giza White and Grey Giant Flander rabbits in Egypt. *Journal Applied Rabbit Research,* **12** : 273-277.

Baselga, M., Gomez, E., Chifre, P. and Camacho, J. (1992). Genetic diversity of litter size traits between parities in rabbits. *5th World Rabbit Congress*, Corvallis, Oregon.

Becker, W. A. (1984). *Manual of Quantitative Genetics.* Academic Enterprises, Pulman, U.S.A.

Blasco, A. (1996). Genetics of litter size and does fertility in the rabbit. *6th World Rabbit Congress*, 9-12 July, 1996, Toulouse, France, **2** : 219-227.

Blasco, A., Ouhayoun, J. and Masoero, G. (1992). Status of rabbit meat and carcass : Criteria and terminology. *Options Mediterraneennes*, Serie Seminaries, **17** : 105-120, Spain.

Livestock *Production Science*, 34 : 165-174.

Cervera, C., Fernandez-Carmona, J., Viudef, P. and Blas, E. (1993). Effect of remating interval and diet on the performance of female rabbit and their litters. *Animal Production*, **56** : 399-405.

Duncan, D. B. (1955). Multiple range and multiple F Tests. *Biometrics*, **11** : 1-42.

El-Raffa, A. M. (1994). Some factors affecting economical productive and reproductive traits in rabbits. Ph. D. Thesis, Faculty of Agriculture, Alexandria University, Egypt.

El-Raffa, A. M., Kosba, M. A., Bahie El-Deen, M. and Zimmermann, E. (1997). Phenotypic and genetic analysis for preweaning mortality in rabbits. *Egyptian Journal Poultry Science*, **17** (1) : 1-14.

El-Zanfaly, E. S. (1996). Genetic and phenotypic analysis for some reproductive traits in rabbits. M.Sc. Thesis, Faculty of Agriculture at Moshtohor, Zagazig University, Egypt.

Facchin, E. (1992). Artificial insemination in rabbit. *Journal Applied Rabbit Research*, **15** : 95-103.

Ferraz, J. B. S. and Eler, J. P. (1994). Use of different animal models in prediction of genetic parameters of 23 traits of Californian and New Zealand White rabbits raised in tropics and suggestion of selection criteria. *5th World Congress on Genetics Applied to Livestock Production*. **20** : 348-351. Guelph, Ontario, Canada.

Garcia, F., Baselga, M., Blasco, A. and Deltoro, J. (1982). Genetic analysis of some productive traits in meat rabbits. I. Numeric traits. *2nd World Congress on Genetics Applied to Livestock Production*, Madrid, Spain, **7** : 557-562.

Gomez, E. A., Rafel, O., Ramon, J. and Baselga, M. (1996). A genetic study of a line selected on litter size at weaning. *6th World Rabbit Congress*, Toulouse, **2** : 289-292.

Harvey, W. R. (1990). User's Guide for LSMLMW and MIXMDL. The Ohio State University, Columbus, OH, USA.

Henderson, C. R. (1972). Sire evaluation and genetic trends. *Animal Genetic Symposium*, American Society Animal Science, American Dairy Science Association, Champaign, IL.

Henderson, C. R. (1984). Application of linear models in animal breeding. University of Guelph, Guelph, Ontario, Canada.

Henderson, C. R. (1988). Theoretical basis and computational methods for a number of different models. *Journal Dairy Science*, **7** (Supplement 2) : 1-16.

Khalil, M. H. (1994). Lactational performance of Giza White rabbits and its relation with pre-weaning litter traits.*Animal Production*, **59**:141-145.

Khalil, M. H., Afifi, E. A. and Kadry, A. E. H. (1989). Genetic analysis of weight of doe rabbits during gestation and its phenotypic relationship with reproductive efficiency at kindling. *Journal Applied Rabbit Research, **12** : 45-51.*

Khalil, M. H., Afifi, E. A. and Owen, J. B. (1987). A genetic analysis of body weight traits in young Bouscat and Giza White rabbits. *Animal Production*, **45** : 135-144.

Krogmeier, D., Dzapo, V. and Mao, I. L. (1994). Additive genetic and maternal effects on litter traits in rabbits. *Journal Animal Breeding* Genetic, **111** : 420-431.

Lange, E. and Schlolaut, W. (1988). The influence of postpartum insemination on litter size and growth of New Zealand White rabbits. 4th World Rabbit Congress, Budapest, October 1988, Hungary Vol. **1** : 130-140.

Lukefahr, S. D., Hohenboken, W. D., Cheeke, P. R. and Patton, N. M. (1990). Prediction and causation of litter market traits from preweaning and weaning characteristics in commercial meat rabbits. *Journal Animal Science*, **68** : 2222-2234.

Maertens, L., Vermeulen, A. and De Groote, G. (1988). Effect of post-partum breeding and pre-weaning litter management on the performances of hybrid does. *4th World Rabbit Congress*, Budapest, October 1988, Hungary **1**, 141-149.

Masoero, G., Ubertalle, A., Mazzocco, P. and Battaglini, L. M. (1985). Terminal crossing of New Zealand White and Californian rabbits. 1. Characteristics on the live animal. Annalidell Istituto Sperimentale per la Zootecnia, **18** (2) : 93-109.

Rochambeau, H. De, Bolet, G. and Tudela, F. (1994). Long term selection-comparison of two rabbits strains. *5th World Congress on Genetics Applied to Livestock Production.* **19** : 257-260, Guelph, Ontario, Canada.

Szendro, Z. (1989). A note on the effect of post-partum breeding on doe productivity. *Journal Applied Rabbit. Research*, **12** : 84-85.

Vicente, J. S. and Garcia, F. (1993a). Effects of strain and embryo transfer model (embryos from one versus two donor does/recipient) on results of cryopreservation in rabbit. *Reproduction Nutrition Development.*, **33** : 5-13.

Vicente, J. S. and Garcia, F. (1993b). Effect of recipient doe on survival rate at birth of frozen rabbit embryos. *Reproduction Nutrition Development.*, **33** : 229-234.

Wu Zhan-Fu , Wu-Fu Yang Zheng and Jian-Yun Chang Zhang, (1996). The determination of simplified selection index of reproductive characters in Saibei rabbits and its diagram calculation. *6th World Rabbit Congress*, 9-12 July 1996, Toulouse, France **2** : 385-388.