Proc. 3rd All Africa Conf. Anim. Agric. & 11th Conf. Egyptian Soc. Anim. Prod., Alexandria, Egypt, 6-9 November 2000: 53- 59

GENETIC EVALUATION OF LIFETIME PRODUCTION TRAITS USING SINGLE-TRAIT AND MULTI-TRAITS ANIMAL MODELS IN NEW ZEALAND WHITE RABBITS

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SUMMARY

Data on 14210 litters of New Zealand White rabbits produced by 2945 does mothered by 1613 dams were analysed to compute variance components and heritabilities of lifetime production traits. These traits included total number born (TNB), total number born alive (TNBA), total number weaned (TNW), and length of lifetime production (LT). For animals with and without records, transmitting abilities (PTA) for these traits were predicted using single-trait (SAM) and multi-traits (MAM) animal models taking into account the relationship coefficient matrix among animals (A^{-1}). Heritability for LT was low (0.09), while the estimates for litter-size traits (*i.e.* TNB, TNBA and TNW) were moderate and ranged from 0.16 to 0.21. For the list of all dams with records, the ranges in estimates of PTA obtained by the MAM vs SAM were 20.6 vs 11.8 bunnies for TNB, 21.08 vs 10.8 bunnies for TNBA, 11.3 vs 7.1 bunnies for TNW and 1.01 vs 0.82 month for LT. The percentages of dams with positive values of PTA obtained by the MAM vs those obtained by the SAM were 97.4 vs 48.2% for TNB, 97.3 vs 49.2 % for TNBA, 99.4 vs 50.8% for TNW and 87.2 vs 50.9% for LT. Percentages of dams with records common between the SAM and MAM procedures were moderate or high and ranged from 53.1 to 69.0%. The percentages of dams remaining in the same position when using the two models were almost equal to zero. Estimates of PTA for animals without records showed the same trend obtained for animals with records.. The positive estimates obtained for maternal grand-dams ranged from 44.2 to 47.7% when using the SAM vs 60.3 to 87.1% when using the MAM, while the respective estimates recorded for maternal grand-sires ranged from 43.2 to 45.9% and from 68.6 to 92.4%. Most correlations among ranks of PTA estimated by the SAM and those estimated by the MAM were relatively moderate or low.

*Keywords: **Rabbits, intensive production, lifetime production traits, animal model, heritabilities, transmitting abilities***

INTRODUCTION

The overall productivity of a doe depends on its lifetime production rather than on a single parity performance. A number of factors, viz. total period of a doe stays in the herd, number of completed kindlings and total number of bunnies kindled during its entire lifetime determine the economic merit of her productive life. From the economic point of view, does with a long productive life along with high level of production would be desirable and effective in genetic improvement. Although there are rather few publications on this concept, Rinaldo and Bolet (1988) observed that does with higher production levels remain in productive status for a long time.

The objectives of the present study were: (1) to estimate genetic and phenotypic variances and heritabilities for lifetime production traits of New Zealand White rabbits raised in high intensive system of production, (2) to predict the transmitting abilities (PTA) of animals with and without records for these traits using single-trait (SAM) and multi-traits (MAM) animal models, and (3) to detect whether the ranking of PTA estimated by the SAM procedure will be different from ranking of PTA estimated by the MAM procedure for the same trait.

MATERIALS AND METHODS

Animals and management

Data on New Zealand White rabbits (NZW) were collected at ZIKA Nucleus Breeding Farm, (Schweizerhof Untergroningen) in Germany over 14 consecutive years of intensive production started from 1982. The females were inseminated firstly at a mean age of 121 days (about 4 months) whereas the mean age at kindling was 153 days (about 5 month). The intensive-breeding schedule in this rabbitry was allowed to get a maximum number of 8-10 litters per doe. The does were inseminated artificially within the first few days after kindling. All inseminations were made at random with a restriction of avoiding close relative matings. Litters were weaned mostly at the age of about 28 days. Details of housing and feeding were described by Youssef *et al.* (2000).

Data structure and traits of lifetime production

The lifetime production traits measured per doe during her productive life (i.e. all litters produced by the doe) were: total number born (TNB), total number born alive (TNBA), total number weaned (TNW) and length of productive life (LT). Lifetime production for the doe was calculated by summing all records of the doe for the four traits (TNBA, TNB, TNW and LT), after making appropriate adjustments. A total of 14210 litters produced from 2945 does, the daughters of 1613 dams were used. The number of bunnies weaned was 88824.

Estimation of variance components and heritabilities

Using REML procedure (SAS procedure guide, 1996), variance were estimated for pre-corrected lifetime production traits of the doe (data corrected for the effects of year-season of kindling and parity). This method is an iterative method and solving the equations of random effects is much more economical procedure than inversion of matrix (John *et al.*, 1984). Iterations are continued using the estimators of dam and error variances from the preceding round of iteration until the estimates are stabilised. The model in matrix notation was:

$$Y = X\beta + Z_d U_d + e$$

Where Y= vector of observed lifetime production trait β= vector of fixed effects of year - season of birth of doe and litter size in which the doe was born; X = Design incidence matrix which relates records to fixed effects; U_d = vector of random effect of dam Z_d =Design incidence matrix which relates records to random dam effects; e = vector of random remainder effect. Since parity in which the doe was born is not available in data and the permanent environment is a combination of dam × parity × litter size in which the doe was born, therefore, the permanent environmental effect was not included in the model. Variance components estimated by REML procedure were used for estimating heritabilities (h^2) of lifetime production traits as: $h^2 = 4\ \sigma^2_d/(\sigma^2_d + \sigma^2_e)$ where σ^2_d and σ^2_e were variances due to effects of dam and remainder, respectively. Approximate standard errors for heritability were calculated by the formula described by Becker (1984).

Prediction of transmitting abilities

Multi-traits animal model program (PEST, 1990) written by Groeneveld *et al.* (1990) was used in predicting the transmitting abilities of animals (PTA) for lifetime production traits. This computer program considers all the available pedigree information when calculating the inverse of the numerator relationship matrix (Ferraz and Johnson, 1993). The transmitting abilities were estimated for lifetime production traits of all animals with records and without records taking into account the relationship coefficient matrix among animals (A^{-1} matrix). To solve the set of mixed model equations, IOD-GS solver (*i.e.* Gauss-Seidel solver with iteration on data described in PEST program) was used. The animal model in matrix notation used was:

$$Y = X\beta + Z_a U_a + e$$

Where: Y, X, β and e have similar meanings as in the previous model; U_a is the vector of random effect of animal; Z_a is the incidence matrix relating records to the additive genetic effects; e is the vector of random error ($I_n\sigma^2e$). According to Meyer (1991&1993), U_a estimated from the animal model is relevant to the BLUP.

RESULTS AND DISCUSSION

Random components of variance and heritabilities

Dam (σ^2_d) and error (σ^2_e) variance components and heritabilities (h^2) estimated for lifetime production traits in New Zealand White rabbits are presented in Table 1. Heritability for LT was low (0.09), while the estimates for litter-size traits (*i.e.* TNBA, TNB and TNW) were moderate and ranged from 0.16 to 0.21. The low estimates of σ^2_d and h^2 for LT were expected since this interval trait is mainly dependent on the management decisions in terms of postpartum insemination, frequency of insemination, buck semen characteristics, lactation status of the doe (lactating or non-lactating), adaptability of does to the controlled system of housing,....etc. The moderate estimates of h^2 for litter-size traits indicate that litter variation in which the doe was born (*i.e.* dam variability) were moderate in terms of intense of lactation, litter-size, litter weight, ... etc. As mentioned before, estimates of σ^2_d and

h^2 for lifetime production traits in rabbits were not available in the literature to compare them with those of the present study. For other polytocus animals like mice, Nagai *et al.* (1988) using bivariate mixed model analysis under a full-sib model reported that h^2 for LT was very low (0.06). In swine, Triebler (1988) reported that h^2 estimated from dam-daughter regression model for LT was moderate (0.22 ± 0.07).

Table 1. Estimates of dam (σ^2_d) and remainder (σ^2_e) variances and heritabilities (h^2±SE) for lifetime production traits in New Zealand White rabbits

Trait	Symbol	Dam		Remainder		σ^2_e/σ^2_d	h^2 ±S.E
		σ^2d	V%+	σ^2e	V%+		
Total number born	**TNB**	15.56	5.2	283.48	94.8	18.2	0.21 ±0.014
Total number born alive	**TNBA**	13.30	4.7	272.70	95.3	20.5	0.19 ±0.013
Total number weaned	**TNW**	7.51	4.1	176.25	95.9	23.5	0.16 ±0.011
Length of lifetime production	**LT**	0.16	2.4	6.63	97.7	41.4	0.09 ±0.006

+Percentages of dam or remainder component of variance relative to the total phenotypic variance.

Based on number of records used in the present study (about 14210 litters born and weaned and 88824 bunnies weaned) along with the small standard errors for heritabilities (ranged from 0.006 to 0.014), the estimates of heritability were reliable and precise (Table 1). Data of the present work generated a homogenous number of daughters per dam along with sufficient number of dams (1613 dams) which lead to provide connections between cells. But, this data was collected from undesigned experiment, which may lead to a downward bias in estimates of heritability. McCarter *et al.* (1987) found that estimates of heritability from designed experiments were higher than those estimates obtained from the field data.

Transmitting abilities estimated for the animals with records

The minimum and maximum estimates of transmitting abilities predicted (PTA) for the animals with available records and their ranges (Table 2) indicate that the MAM procedure recorded higher ranges in estimates of PTA for all traits than those recorded by the SAM procedure. The ranges in estimates of PTA predicted recorded by the MAM vs SAM were 20.6 vs 11.8 bunny for TNB, 21.08 vs 10.8 bunny for TNBA, 11.3 vs 7.1 bunny for TNW and 1.01 vs 0.82 month for LT.

Table 2. Minimum, maximum and ranges of transmitting abilities for dams with records (PTA) predicted by single-trait and multi-traits animal models for lifetime production traits in New Zealand White rabbits

Trait+	*Single-trait animal model*			*Multi-traits animal model*		
	Minimum	Maximum	Range	Minimum	Maximum	Range
TNB	-5.00	6.80	11.80	-2.00	18.70	20.60
TNBA	-4.70	6.10	10.80	-3.35	17.70	21.08
TNW	-3.10	4.00	7.10	-0.90	11.50	11.30
LT	-0.35	0.47	0.82	-0.21	0.80	1.01

+ Traits as defined in Table 1.

The number of dams with records (and their percentages) with positive transmitting abilities (Table 3) indicate that estimates recorded by the MAM were higher in PTA than those figures recorded by the SAM. However, the percentages of dams with positive PTA recorded by the MAM vs those recorded by the SAM were 97.4% vs 48.2% for TNB, 97.3% vs 49.2 % for TNBA, 99.4% vs 50.8% for TNW and 87.2% vs 50.9% for LT (Table 3). Mrode (1996) reported that evaluation using the MAM is the optimum methodology to evaluate animals using all traits, because it accounts for the relationships among animals and traits under questions.

For the list of the top 30% of dams with records, the percentages of dams common (DC%) between the SAM and MAM procedures for TNB, TNBA, TNW and LT were 55.2, 58.7, 53.1 and 69.0%, respectively. These moderate or high estimates of DC% obtained by the SAM procedure for the list of the top 30% of dams are nearly similar to those obtained by the MAM for the same list of dams. On the opposite side, the percentages of dams remaining in the same position (*i.e.* without changing their ranks) were almost very low and ranged from 0.6 to 0.8%. This leads to state that the SAM procedure had different trends in evaluating dams compared with the MAM. Thus, covariances among lifetime production traits in connection with A^{-1} may have a great role in solving the iterative equations of dams with records in the MAM procedure.

Table 3. Numbers of dams and their percentages (animals with records) with positive transmitting abilities (PTA) predicted by single–trait and multi-traits animal models for lifetime production traits in New Zealand White rabbits

Trait[+]	*Single-trait animal model*		*Multi-trait animal model*	
	No. of dams	% of dams	No. of dams	% of dams
TNB	778	48.2	1571	97.4
TNBA	793	49.2	1569	97.3
TNW	819	50.8	1603	99.4
LT	821	50.9	1407	87.2

[+] Traits as defined in Table 1.

Transmitting abilities estimated for the animals without records

The minimum and maximum estimates of transmitting abilities and their ranges for the animals without records (maternal grand-dams and maternal grand-sires) indicated that these estimates had the same trend obtained for the list of dams with records (Table 4). The ranges in transmitting abilities for lifetime production traits of maternal grand-dams estimated by the MAM vs SAM were 9.5 vs 5.6 bunny for TNB, 14.7 vs 4.9 bunny for TNBA, 7.9 vs 3.3 bunny for TNW and 0.49 vs 0.35 month for LT. The respective ranges in transmitting abilities for the list of maternal grand-sires estimated by the MAM vs SAM were 16.4 vs 7.6 bunny, 15.4 vs 7.6 bunny, 8.9 vs 4.6 bunny and 0.6 vs 0.55 month. These high ranges in estimates of transmitting ability indicated that the evaluation of dams based on records of their parents (maternal grand-dams together with maternal grand-sires) may be effective in improving lifetime production traits in rabbits.

Table 4. Minimum, maximum and ranges of transmitting abilities for lifetime production traits of maternal grand-dams and maternal grand-sires (animals without records) estimated by single-trait and multi-traits animal models in New Zealand White rabbits

Trait[+]	*Maternal grand-dams*			*Maternal grand-sires*		
	Minimum	Maximum	Range	Minimum	Maximum	Range
Single-trait animal model:						
TNB	-2.80	2.80	5.60	-3.80	3.80	7.60
TNBA	-2.30	2.60	4.90	-3.30	4.20	7.60
TNW	-1.40	1.90	3.30	-1.90	2.70	4.60
LT	-0.18	0.17	0.35	-0.29	0.26	0.55
Multi-traits animal model:						
TNB	-1.90	8.60	9.50	–2.10	13.30	1.40
TNBA	-3.10	11.60	14.70	-3.70	12.70	15.40
TNW	-0.40	7.50	7.90	-0.60	8.30	8.90
LT	-0.10	0.39	0.49	-0.15	0.45	0.60

[+] Traits as defined in Table 1.

The number of maternal grand-dams and maternal grand-sires (and their percentages) with positive transmitting abilities for lifetime production traits (Table 5) indicate that transmitting abilities recorded by the MAM were much higher than those recorded by the SAM. The positive estimates recorded for maternal grand-dams ranged from 44.2 to 47.7% for the SAM vs 60.3 to 86.1% for the MAM, while the respective estimates recorded for maternal grand-sires ranged from 43.2 to 45.9% and from 68.6 to 92.4% (Table 5). High positive estimates of transmitting ability recorded by the MAM for all lifetime production traits lead to state that it is advisable to combine all these traits in one animal model instead of using the SAM procedure to select animals without available records.

For the list of the top 30% of animals without records, percentages of animals common between the two animal models were high and ranged from 50.5 to 77.4% for maternal grand-dams and from 33.0 to 59.6% for maternal grand-sires (Table 6). High ranges recorded by the maternal grand-dams relative to the maternal grand-sires indicate that selection of maternal grand-dams based on their daughters' records may be more effective than selection of maternal grand-sires for improving lifetime production traits in rabbits. The percentages of animals that didn't change their rank were very low and ranged from 0.0 to 4.3% for the list of all maternal grand-dams and from 0.0 to 6.0% for the list of all maternal grand-sires (Table 6). Consequently, evaluation of animals without records using the MAM procedure will give different trends with more accuracies comparable to the evaluation using the SAM.

Table 5. Numbers of animals and percentages (animals without records) with positive transmitting abilities for maternal grand-dams and maternal grand-sires recorded by single-trait and multi-traits animal models for lifetime production traits in New Zealand White rabbits

Trait+	*Single-trait animal model*		*Multi-traits animal model*	
	No. of animals	% of animals	No. of animals	% of animals
Maternal grand-dams:				
TNB	142	45.8	219	70.6
TNBA	147	47.1	255	82.3
TNW	137	44.2	276	86.1
LT	148	47.7	187	60.3
Maternal grand-sires:				
TNB	232	44.4	430	82.2
TNBA	226	43.2	460	88.0
TNW	234	44.7	483	92.4
LT	240	45.9	359	68.6

+ Traits as defined in Table 1.

Table 6. Percentages of maternal grand-dams (MGDC%) and maternal grand-sires (MGSC%) common and remaining in the same position (MGDR% and MGSR%) recorded by single-trait vs multi-traits animal models for the top 30 % of animals without records

Trait+	*Maternal grand-dams*		*Maternal grand-sires*	
	MGDC%	**MGDR%**	**MGSC%**	**MGSR%**
TNB	50.5	1.1	35.8	0.0
TNBA	58.1	0.0	33.0	3.7
TNW	59.1	0.0	44.0	3.7
LT	77.4	4.3	59.6	6.0

+ Traits as defined in Table 1.

Correlations among ranks of transmitting abilities estimated by the SAM vs MAM

The correlations among ranks of transmitting abilities were computed using the SAS program (SAS procedure guide, 1996). The correlations (and their significance) among ranks of transmitting abilities estimated by the SAM and MAM procedures for different lifetime production traits are shown in Table 7 for both animals with and without records. For both animals with and without records, most correlations among ranks of transmitting abilities estimated by the SAM vs MAM procedure for all lifetime production traits were moderate or low (29 of the estimates out of 48 were less than 0.4). These estimates indicated that ranking of transmitting abilities estimated by the SAM differed from the ranking of transmitting abilities estimated by the MAM. This was expected since covariances between traits play an important role in the accuracy of the BLUP estimated by the MAM (Mrode, 1996).

Table 7. Correlations among ranks of transmitting abilities estimated by single-trait and multi-traits animal models for animals with and without records for lifetime production traits[+]

Multi-traits animal model	Grand parents[++]	Single-trait animal model TNBA	TNB	TNW	LT
Animals with records:					
TNB		0.37***	0.45***	0.40***	0.34***
TNBA		0.41***	0.36***	0.39***	0.28***
TNW		0.42***	0.42***	0.51***	0.36***
LT		0.51***	0.54***	0.59***	0.76***
Animals without records:					
TNB	**MGS**	0.22***	0.30***	0.25***	0.23***
	MGD	0.33***	0.40***	0.36***	0.23***
TNBA	**MGS**	0.62***	0.19***	0.25***	0.16***
	MGD	0.35***	0.27***	0.32***	0.11***
TNW	**MGS**	0.26***	0.26***	0.38***	0.23***
	MGD	0.35***	0.34***	0.50***	0.21***
LT	**MGS**	0.47***	0.50***	0.54***	0.15***
	MGD	0.44***	0.47***	0.55***	0.80***

[+] Traits as defined in Table 1.
[++]**MGS**= Maternal grand-sires, **MGD**= Maternal grand-dams.
***= P<0.001.

CONCLUSIONS

- Estimates of heritability of lifetime production traits were moderate.
- The values and ranges of transmitting abilities recorded by the multi-traits animal model were higher than those estimated by single-trait animal model for both animals (with and without records).
- The values of transmitting abilities and the ranges recorded for animals with records were higher than those estimated for the list of animals without records (paternal grand-dams, and maternal grand-dams) for all traits studied.
- High correlations (near to unity) among ranks of transmitting abilities estimated by single-trait Animal Model for animals with and without records lead to conclude that: selection based on Animal Model including single lifetime litter-size trait could be an effective method to improve the other traits of lifetime production (*e.g.* litter size at birth and weaning, litter weight...*etc.*).

ACKNOWLEDGMENTS

The authors are gratefully acknowledging the ZIKA Nucleus Breeding Farm (Schweizefhof untergroningen) in Germany for supplying the data.

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