Estimation of heritability and repeatability for maternal and milk production traits in New Zealand White rabbits raised in hot climate conditions

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Abstract

This experiment involved 364 records of litter and milk production produced from 127 does of New Zealand White rabbit (NZW) breed to estimate heritability and repeatability for doe, litter and milk yield traits. Doe traits such as doe body weight (DBW) and doe production efficiency (DPE); litter traits such as litter size and weight at birth (LSB and LWB), 21 d (LS21 and LW21) and weaning at 28 d (LSW and LWW) and litter gain weight during the periods of 1-21 d (LGW1-21), 21-28 d (LWG21-28) and 1-28 d (LWG1-28); litter milk efficiency (litter gain / milk intake) during the period of 1-21 d (LME1-21); milk coefficients during the periods of 1-21 d (MC1-21), 21-28 d (MC21-28) and 1-28 d (MC1-28); and milk yield traits (g) of each doe during the periods of 1-21 d (MY1-21), 21-28 d (MY21-21) and 1-28 d (MY1-28) were studied. A repeatability single trait animal model was used to analysis of the data.

Estimates of heritabilities (repeatabilities) for DBW and DPE were 0.0 and 0.09 (0.66 and 0.09), respectively. For LSB, LS21, LSW, LWB, LW21, LWW, LGW1-21, LGW21-28 and LGW1-28 heritabilities (repeatabilities) were 0.04, 0.0, 0.0, 0.0, 0.05, 0.07, 0.04, 0.0 and 0.6 (0.27, 0.15, 0.15, 0.21, 0.07, 0.08, 0.04, 0.06 and 0.07), respectively. Heritabilities (repeatabilities) of 0.01, 0.11, 0.08, 0.10, 0.0, 0.0 and 0.11 (0.04, 0.15, 0.11, 0.11, 0.09, 0.11, 0.10, 0.11 and 0.11) were obtained for LME1-21, MC1-21, MC21-28, MC1-28, MY1-21, MY21-28 and MY1-28, respectively. From the previous estimates of heritability and repeatability, it is concluded that selection of NZW does for traits of DPE, LWW, MC1-21 and MY1-28 could be efficient to improve these traits in NZW rabbits, while culling strategies of the does for traits of DBW, LSB and LWB could be appropriate to improve litter traits under the Egyptian hot climate conditions.

Keywords: doe litter traits, heritability, permanent environmental effects

Introduction

Doe and litter traits are the most important characters for prolificacy of the rabbit doe and survival rate of litters during suckling period. Litter milk efficiency, milk coefficient and lactation patterns for NZW rabbits were studied by many investigators (El-Maghawry et al 1993; El-Sayiad 1994; Khalil 1994; Nasr 1994 and Khalil et al 2004). Early litter growth and mortality rate in rabbits depend in part on the intrinsic ability of the doe to provide adequate milking ability with better maternal environment. Milk yield of the doe is the major pronounced postnatal maternal component influencing pre-weaning litter growth in terms of litter size and litter weight (Nasr 1994 and El-Raffa et al 1997).

Litter weight at birth and number of suckling kits both strongly influencing milk production of rabbit doe (El-Maghawry et al 1993 and Pascual et al 1996). With increasing litter weight at birth, milk production increases as a consequence of the uterine induction. Likewise, milk production of does could be increased as the number of suckling kids increased (Bolet et al 1996 and Petersen et al 1996). Ayyat et al (1995) and Lukefahr et al (1996) stated that milk production might be limited by additive gene effects and being positively correlated with litter weight at birth (Lukefahr et al 1983; Khalil 1994 and Petersen et al 1996), permits the assumption that the effect of the number of the assigned kids to the nursing doe on milk production is not independent on the litter weight at birth.

Although, estimates of heritability and repeatability for doe, litter and lactation traits were mostly low and have a broad range among reports, as reviewed by Khalil et al (1986). It could be improved by selection and/or culling strategies (Afifi et al 1989, Lukefahr and Hamilton 1997). Few reports on genetic analysis for doe litter and milk production traits using repeatability animal model are available in the Egyptian literature (Ferraz et al 1992 and Hassan 2005). The aims of this experiment were to estimate heritability, permanent environmental effects and repeatability for doe, litter and lactation traits in New Zealand White rabbits in hot climate conditions using repeatability single trait animal model analysis.

Materials and methods

Animals and management

This experiment was carried out at the Rabbitry of Faculty of Agriculture at Moshtohor, Benha University, Egypt during the period from 2001 to 2003 on New Zealand White (NZW) breed. This breed came from Bank El-Nil rabbitry since 1994. Bucks and does were individually housed in wire cages with standard dimensions arranged in one-tire batteries allocated in rows along the rabbitry with passages suitable for service. Each buck was mated to 4 or 5 does (at 6 month of age).

The does were assigned randomly according to the available numbers. Does were mated in the bucks' cage and lodged individually. Sire-daughter, full and half sib matings were avoided. Each doe was palpated 10 days thereafter to detect pregnancy. Those, which failed to conceive, were returned to the same mating-buck at the day of test. Metal nest boxes were provided at 27 days after fertile mating. Does were remated 10 days after kindling. Weaning of litter was done four weeks after kindling. Breeding animals were fed *ad libitum* on a pelleted rabbit ration containing 17.7 % crude protein, 13 % crude fiber and 2.54 % fat. In winter and early months of spring, berseem (*Trifolium alexandrium*) was supplied at midday. Cages of all animals were cleaned and disinfected regularly before each kindling. All animals were medicated similarly and they were subjected to the same managerial and climatic conditions throughout the experimental period.

Data and models of analysis

Data collected on 364 litters produced from 127 does fathered by 35 sires and mothered by 66 dams of NZW breed (Table 1).

Table 1. Structure of the data analyzed for New Zealand White rabbits

Item	Numbers
Sires	35
Dams	66
Does	127
Litters	364
Total number of animals in the pedigree file	205*

**This number is less than of the total summing because of some dams represented twice (as a doe and as a dam in the next generation).*

Doe traits such as doe body weight (DBW) and doe production efficiency (DPE) computed as litter weaning weight divided to doe body weight at parturition; litter traits such as litter size and weight at birth (LSB and LWB), 21 d (LS21 and LW21) and weaning at 28 d (LSW and LWW); and litter gain weights were computed during the periods of 1-21 d (LGW1-21), 21-28 d (LWG21-28) and 1-28 d (LWG1-28) were studied. Milk yield (g) of each doe were recorded from 1 to 21 d (MY1-21), from 21 to 28 d (MY21-28) and from 1 to 28 d (MY1-28). Milk production was recorded as an average for the weight of both doe and bunnies before and after suckling. Accordingly, the bunnies were separated from their mothers at 15.00 pm, thereafter the bunnies were allowed to suckle at 8.00 am in the next day. The average of the differences between weight of each doe and their bunnies before and after suckling were calculated. Litter milk efficiency (computed as litter gain in grams divided to milk intake in grams) during the period of 1-21 d (LME1-21), as well as milk coefficients [computed as [milk yield in grams/doe body weight at parturition x the period of milk production in days) x 100] during the periods of 1-21 d (MC1-21), 21-28 d (MC21-28) and 1-28 d (MC1-28) were studied.

Data were analyzed using repeatability single trait animal model analysis (Boldman et al 1995). Variances obtained by REML method of VARCOMP procedure (SAS 1996) were used as starting (guessed) values for the estimation of variance components. Analyses were done according to the general model:

$$y = Xb + Z_1a + Z_2p + e$$

where:
y = vector of observations;
X= incidence matrix of fixed effects (parity and year-season); parity (7 levels) and year-season (8 levels);
Z_1 and Z_2 = incidence matrices corresponding to random effects of additive (a) and permanent environment (p_e, doe effect), respectively;
e = vector of random errors.

Heritability (h^2) and repeatability (t) were computed based on the following equations:

$$h^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_{Pe}^2 + \sigma_e^2} \quad \& \quad t = \frac{\sigma_a^2 + \sigma_{Pe}^2}{\sigma_a^2 + \sigma_{Pe}^2 + \sigma_e^2}$$

where σ_a^2, σ_{Pe}^2 and σ_e^2 are the variances due to effects of additive, permanent environment and error, respectively. Repeatability was expressed as the ratio of variances by summing genetic and permanent environmental variances ($\sigma^2_a + \sigma^2_{pe}$) to phenotypic variance ($\sigma^2_a + \sigma^2_{pe} + \sigma^2_e$). Standard errors of heritability were computed using MTDFREML procedure (Boldman et al 1995).

Results and discussion

Means

Results in Table 2 show the actual means and coefficient of variations for doe, litter and milk production traits to characterize the NZW rabbit population.

Table 2. Actual means, standard deviations (SD) and coefficients of variation for doe, litter and milk production traits in New Zealand White rabbits

Trait	Mean	SD	CV	Minimum	Maximum
Doe traits^{+}*:*					
DBW	3298.2	410.1	12.4	2160	4410
DPE	0.74	0.31	42.2	0.06	2.06
Litter traits^{++}					
LSB	6.74	2.34	34.7	1	14
LS21	5.89	2.20	37.4	1	11
LSW	5.73	2.20	38.4	1	11
LWB	489.6	169.1	34.5	60	980
LW21	1837.0	701.2	38.2	170	3930
LWW	2442.1	1037.2	42.5	180	5300
LGW1-21	1355.9	613.6	45.3	55	3140
LGW21-28	673.7	402.7	59.8	15	1900
LGW1-28	1996.4	931.1	46.6	90	4815
Milk production traits^{+++}*:*					
LME1-21	0.53	0.23	44.5	0.03	1.97
MC1-21	2.94	1.02	34.7	0.55	6.12
MC21-28	2.10	0.98	46.6	0.02	5.06
MC1-28	3.84	1.36	35.5	0.72	7.53
MY1-21	2692.1	917.4	34.1	490	5618
MY21-28	1925.4	878.1	45.6	540	4410
MY1-28	3514.2	1214.5	34.6	788	7018

$^{+}$ *DBW and DPE= doe body weight and doe production efficiency, respectively.*
$^{++}$*= LSB, LS21, LSW, LWB, LW21, LWW, LGW1-21, LGW21-28 and LGW1-28= litter size at birth, litter size at 21 d, litter size at weaning, litter weight at birth, litter weight at 21 d, litter weight at weaning, litter gain weight from 1 to 21 d, litter gain weight from 21 to 28 d and litter gain weight from 1 to 28 d, respectively.*
$^{+++}$ *LME1-21, MC1-21, MC21-28, MC1-28, MY1-21, MY21-28 and MY1-28= litter milk efficiency from 1 to 21 d, milk coefficient from 1 to 21 d, milk coefficient from 21 to 28 d, milk coefficient*

from 1 to 28 d, milk yield from 1 to 21 d, milk yield from 21 to 28 d and milk yield from 1 to 28 d, respectively

Means of the studied traits in Table 2 are within the ranges reviewed in the Egyptian literature (Afifi et al 1989; El-Maghawry 1999; Khalil and Afifi 2000; Nofal et al 2002; Ramadan 2005).

Coefficients of variability (CV %) ranged from 12.4 to 59.8% for doe and litter traits and from 34.6 to 75.7% for milk production traits. This confirms that these traits in rabbits are subjected to many effects such as genetic make up of the does, non-genetic effects (year-season, parity and management of the herd). These trends are in agreement with the results of El-Maghawary (1999) and Ramadan (2005).

Heritability

Results in Table 3 showed that heritability (h^2) estimates for doe traits in NZW were 0.0 for DBW and 0.09 for DPE.

Table 3. Estimates of heritability, permanent and error effects, and repeatability (t) estimates for doe, litter and milk production traits in New Zealand White rabbits

Trait	**h^2±s.e**	**c^2±s.e**	**e^2±s.e**	**Repeatability (t)**
Doe traits^{+}:				
DBW	0.00±0.001	0.66±0.02	0.34±0.02	0.66
DPE	0.09±0.092	0.00±0.09	0.91±0.06	0.09
Litter traits^{++}				
LSB	0.04±0.095	0.23±0.11	0.73±0.06	0.27
LS21	0.00±0.07	0.15±0.09	0.85±0.06	0.15
LSW	0.00±0.06	0.15±0.09	0.85±0.06	0.15
LWB	0.00±0.06	0.21±0.09	0.79±0.06	0.21
LW21	0.05±0.001	0.02±0.001	0.93±0.001	0.07
LWW	0.07±0.001	0.01±0.001	0.91±0.001	0.08
LGW1-21	0.04±0.001	0.00±0.001	0.96±0.001	0.04
LGW21-28	0.00±0.038	0.01±0.001	0.99±0.38	0.01
LGW1-28	0.06±0.001	0.01±0.001	0.93±0.001	0.07
Milk production traits^{+++}:				
LME1-21	0.01±0.06	0.03±0.08	0.96±0.06	0.04
MC1-21	0.11±0.09	0.00±0.09	0.89±0.06	0.11
MC21-28	0.08±0.09	0.01±0.09	0.91±0.06	0.09
MC1-28	0.10±0.09	0.01±0.09	0.89±0.001	0.11
MY1-21	0.00±0.001	0.10±0.001	0.90±0.001	0.10
MY21-28	0.00±0.001	0.11±0.001	0.89±0.001	0.11
MY1-28	0.11±0.001	0.00±0.001	0.89±0.001	0.11

$^{+}$, $^{++}$ and $^{+++}$ traits as defined in Table 2

Zero estimate of h^2 for DBW may be due to higher permanent environmental effects (66%) on this trait (Table 3). But, estimate of h^2 for DPE could be used as selection criteria to improve doe trait in NZW rabbit in this population. Lukefahr and Hamilton (1997) found that h^2 was 0.07 for DPE and 0.53 for DBW when used pooled data collected on purebreds of Californian and New Zealand White rabbits breeds.

Estimates of h^2 for litter traits were low and ranged from 0.0 to 0.04 for litter size traits, from 0.0 to 0.07 for litter weight traits and from 0.0 to 0.06 for litter gain traits. Low estimates of h^2 for these traits also may be due to higher permanent environment and/or non-additive genetic effects than additive effects for all litter size traits, LWB and LGW21-28 (Table 3) (El-Maghawry 1997). It is concluded that permanent environment and non-genetic effects plays a large role in litter size traits in rabbits. Low estimate of h^2 for litter size and weight traits ranging from 0.0 to 0.13 were also obtained by Rollins et al (1963), Johnson et al (1988), Baselga et al (1992), Ferraz et al (1992), Panella et al (1992), Khalil (1994), Ayyat et al (1995), Lukefahr et al (1996), Lukefahr and Hamilton (1997) Baselga and Garcia (2002) and Nofal et al (2002). However, Blasco et al (1993) reported that moderate estimates of h^2 ($0.2< h^2<0.3$) for the components of litter size (i.e., ovulation rate and number of embryos) are encouraging. El- Maghawry (1999) showed low heritabilities of 0.14, 0.12 and 0.13 for daily gain weight (g) per litter during the periods of 1-21 d, 1-28 d and 21-28 d, respectively. Ferraz et al (1992) reported that the contribution of the permanent environmental effect of the doe was moderate for litter traits (ranging from 1.5 to 17.5%). Based on the highest estimates of h^2 for traits of LW21, LWW and LGW1-28 compared to the other traits in this study, it is could be encouraging factor the rabbit breeders to improve litter traits by selection based on predicted breeding values for LWW trait.

Estimates of h^2 for milk production traits in Table 3 are small (0.01 for LME1-21) and ranged from 0.08 to 0.11 for milk coefficient and from 0.0 to 0.11 for milk yield traits. It is showed also that milk coefficients during different intervals were, generally, higher than the other milk production traits. Lukefahr et al (1996) found the same estimate of h^2 (0.11) for total milk yield based on multiple parity in pooled data for two purebreds of Californian and NZW and the two reciprocals. Ayyat et al (1995) reported heritability of 0.04 for 1-4 week total milk yield (adjusted for litter size at birth). However, they found that 1st, 2nd and 3rd week, heritabilities for milk yield ranged from 0.09 to 0.22. El-Maghawry et al (1993) studying similar milk production traits, obtained heritabilities ranged from 0.09 to 0.26. Al-Sobayil et al (2005) found heritabilities for milk yield traits were moderate, ranging from 0.18 to 0.22 when pooled data collected on V-line and Saudi rabbits and all crosses between them. From this experiment, one could conclude that reasonable genetic progress can be obtained by selection for milk production traits, except for LME1-21, MY1-21 and MY21-28.

Permanent environmental effects

Permanent environmental effects given in Table 3 were low and moderate (ranging from 0.0 to 0.23) for all the studied traits, except for DBW which have the highest (0.66) effect of permanent environment. There are many traits have higher effects of permanent than additive effects. These traits are DBW, LSB, LS21, LSW, LWB, LGW21-28, LME1-21, MY1-21 and MY21-28 (Table 3). Therefore, the permanent environmental effects should be considered when studying the doe, litter and milk production traits. Similar results were obtained by El-Maghawry (1997) and Lukefahr and Hamilton (1997).

Repeatability

Estimates of repeatability for all the studied traits given in Table 3 tended to be low to moderate in magnitude (range between 0.04 to 0.27), except for DBW which was highly repeatable (0.66), because it was highly non additive genetic and permanent environmental effects. Lukefahr and Hamilton (1997) previously reported the value of repeatability was 0.72 for this trait. They added that permanent sources of variation were important for doe body weight and also for litter weaning weight. In this study, repeatability estimates of litter size traits were ranged from 0.15 to 0.27. These estimates are within the range of 0.001 to 0.26 reported in the literature (Garcia et al 1982; Baselga et al 1992; Khalil 1994; Lukefahr and Hamilton 1997). Khalil (1994) and Iraqi and Youssef (2006) found that repeatability estimates for lactation traits were low and ranged from 0.002 to 0.189. Because of low repeatability for most traits, it is very advantageous to consider more litters before selecting a doe for these traits. Therefore, culling of does for these traits based on a single production record would not be efficient from a genetic standpoint and consequently assessment of several parities before selecting does for these traits (Khalil and Mansour 1987 and Khalil 1994).

Another point of view, heritability and repeatability estimates for DPE, LGW1-21, MC1-21 and MY1-28 traits were the same, suggesting the absence of non-additive and permanent environmental effects. However, these permanent sources of variation were important for these traits (Lukefahr and Hamilton 1997).

Conclusions

- In spite of estimates of heritability for traits of DPE, LWW, MC1-21 and MY1-28 were low, but there are the highest compared with the other studied traits. Therefore, selection of NZW does could be efficient to improve these traits under the Egyptian hot climate conditions.

- Traits of doe body weight, litter size and weight at birth could be improved by culling strategies of does, because it had the highest repeatability estimates compared to other the studied traits (ranged from 0.21 to 0.66).

- Although, the permanent environmental effects in this study were somewhat low for most the studied traits, but it were higher than additive effects. Therefore, this effect could be considered in repeatability animal model analysis to obtain more accurate estimates of additive variance.

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Received 3 March 2008; Accepted 9 July 2008; Published 5 August 2008

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