Maternal heritability and repeatability for litter traits in rabbits in a humid tropical environment

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Abstract

Data on litter production traits of does, involving 1120 litters, was collected over a 10-year period (1984 to 1994) and analyzed to estimate heritability and repeatability. Locally adapted does and bucks of predominantly New Zealand White breeding were involved. Traits studied were total litter size born and born alive, and litter size and weight at 21 days, 28 days (weaning) and 84 days (marketing). A doe repeatability model was employed which included a fixed contemporary environmental group effect (year–season–doe parity) and litter size at the corresponding age as a linear covariate (for litter weight traits only), and random animal (additive maternal genetic), permanent (non-additive maternal genetic plus permanent environmental), service sire, and residual effects. Heritability (repeatability) estimates for total litter size born and born alive, and litter size at 21 days, 28 days, and 84 days were 0.09, 0.12, 0.06, 0.09, and 0.07 (0.30, 0.32, 0.26, 0.25, and 0.19), respectively. For litter weight at 21 days, 28 days, and 84 days, heritability (repeatability) estimates were 0.08, 0.09, and 0.02 (0.18, 0.19, and 0.09), respectively. In conclusion, litter production traits tended to be lowly heritable and lowly to moderately repeatable.

Keywords: Rabbit; Heritability; Maternal effects; Litter traits

1. Introduction

Limited rabbit genetic studies have been conducted in tropical countries where climate, diet, management, and stock sources can differ markedly from those in temperate countries. Genetic parameter estimates (e.g. heritability and breeding value) are especially needed from tropical rabbit populations in order to provide quality breeding stock to farmers. Reports from Tanzania (Mgheni and Christensen, 1985), Ghana (Lukefahr et al., 1992), Brazil (Ferraz and Eler, 1994), and Hawaii (Moura et al., 1997) tend to indicate higher heritabilities for production traits than is generally reported from temperate environments. In tropical environments, rabbit populations often have a heterogeneous history involving multiple breed introductions and crossings which could explain the higher heritability values reported.
The objectives of this study were to estimate maternal heritability and repeatability for several litter production traits of the doe for application in selection or culling programmes in an experimental herd of predominantly New Zealand White rabbits raised in the humid-tropical environment of Trinidad (West Indies).

2. Materials and methods

2.1. Rabbit type, climate and housing

Data on doe performance traits were collected over a 10-year period (1984 to 1994) from a small experimental rabbitry, established in March, 1983, at the UWI, Trinidad. Locally adapted rabbits of mixed breeding (including contributions from New Zealand White, Californian, Checkered Giant, etc.), purchased from pet keepers and a few small rabbitries, served as the foundation stock. The herd was closed by the end of 1983 with 10 does and three bucks. However, the herd continued to expand to reach a total of 35 breeding does by the end of 1994. During the period of this study, the herd was opened a few times to introduce bucks from outside sources (four in 1985, two in 1987 and one in 1988) in order to keep the level of inbreeding low (Rastogi and Heyer, 1992).

The Trinidad climate is humid-tropical with average relative humidity varying between 80 and 85%. Daily temperature inside the rabbitry varied between 25 and 36°C. There is a major dry season from January to May and a short one in October. The mean annual rainfall is 1700 mm. Animals were housed in a well-ventilated building with all-wire cages and had access to automatic waterers and feeders.

2.2. Breeding management

An 11- to 14-day remating schedule was followed. A group rotation breeding scheme was practised whereby each doe was randomly assigned to the same buck for the entire period of her reproductive life. This scheme used together with pedigree information helped to avoid matings among closely related animals. Does were palpated for pregnancy 14 days after service. If not pregnant, the doe was immediately rebred. On day 28 of gestation, the nest box was presented. Cross-fostering of kits among does was not practised so that a doe’s own producing ability could be assessed. Does were culled for poor fertility and productivity (i.e. failure to wean at least a total of 12 kits during the first three consecutive matings). Male replacements were selected for post-weaning growth until breeding age of 6 months, whereas doe replacements were selected at weaning from dams with larger than average litters over the first three kindlings and with below average inter-kindling period. However, the amount of applicable selection pressure was rather low due to small flock size. In selecting replacement breeding stock, preference was given to all-white rabbits.

2.3. Traits studied

Total litter size born and born alive, and litter size and weight at 21 days, 28 days (weaning), and 84 days (marketing) were measured. Obviously, litter traits measured on day 84 after kindling cannot be strictly regarded as doe performance traits. Nonetheless, our interest was in determining the degree of maternal influence. Of the recorded litters, those which did not survive to weaning (<4%) were eliminated from the data set. Descriptive statistics for all traits studied are presented in Table 1. Table 2 shows the number of animals included and the structure of the data used in the genetic analysis. It should be noted that the number of base animals and dams are different because missing records were deleted from the data set.

2.4. Statistical procedures

A repeatability animal model was employed to estimate genetic and environmental variances for litter production traits of the doe by AIREML (average information restricted maximum likelihood) as developed by Johnson and Thompson (1995). The model terms included the fixed effect of year–season–doe parity to represent contemporary environmental subgroups, random doe (additive maternal genetic), permanent maternal (non-additive maternal genetic plus permanent environmental), service sire of the litter, and residual (temporary
Table 1
Means, standard deviation and range for maternal performance traits analysed

<table>
<thead>
<tr>
<th>Trait</th>
<th>Mean</th>
<th>S.D.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>Total litter size born</td>
<td>5.3</td>
<td>1.52</td>
<td>1</td>
</tr>
<tr>
<td>Litter size born alive</td>
<td>5.2</td>
<td>1.55</td>
<td>1</td>
</tr>
<tr>
<td>Litter size at 21 days</td>
<td>4.6</td>
<td>1.48</td>
<td>1</td>
</tr>
<tr>
<td>Litter size at 28 days (weaning)</td>
<td>4.6</td>
<td>1.48</td>
<td>1</td>
</tr>
<tr>
<td>Litter size at 84 days (marketing)</td>
<td>4.2</td>
<td>1.52</td>
<td>1</td>
</tr>
<tr>
<td>Litter wt. at 21 days, g</td>
<td>958</td>
<td>168</td>
<td>120</td>
</tr>
<tr>
<td>Litter wt. at 28 days, g</td>
<td>1304</td>
<td>222</td>
<td>180</td>
</tr>
<tr>
<td>Litter wt. at 84 days, g</td>
<td>6455</td>
<td>846</td>
<td>1100</td>
</tr>
</tbody>
</table>

Maternal environmental and possible genetic contribution of the litter) effects. For litter weight traits, the model also included litter size at the corresponding age as a linear covariate. Within each year, two seasons were considered (dry = January to May, wet = June to December). There were three doe parity classes (first, second through fifth, and sixth through 12th). Additive maternal genetic, non-additive maternal genetic plus permanent environmental, service sire of the litter, and residual effects were assumed to be normally and independently distributed with mean 0 and variances \( \sigma_a^2 \), \( \sigma_p^2 \), \( \sigma_e^2 \), respectively.

Maternal heritability was computed by expressing \( \sigma^2_a \) as a proportion of the total phenotypic variance \( \sigma^2_t = \sigma^2_a + \sigma^2_p + \sigma^2_e \). To estimate repeatability, variance components due to additive maternal genetic and permanent effects were summed together \( \sigma^2_a + \sigma^2_p \) and expressed as a proportion of the total phenotypic variance. Standard errors for ratios of \( \sigma^2_a \) and \( \sigma^2_p \) to \( \sigma^2_t \) were computed from AIREML analyses, however standard errors for repeatability could not be directly obtained from the analysis.

3. Results and discussion

3.1. Heritability estimates for maternal performance traits

In general, maternal heritabilities for all litter traits investigated were low and non-significantly different from zero \( (0.02 \leq h^2 \leq 0.12, \text{ Table 3}) \). For litter size at various ages, heritability estimates varied between 0.06 for litter size at 21 days and 0.12 for litter size born alive. At present, consensus exists that heritability of litter size in rabbits (and other prolific species) is generally around 0.1 (Randi and Scosio, 1980; Johnson et al., 1988; Afifi et al., 1992; Baselga et al., 1992; Ferraz et al., 1992; Panella et al., 1992; Blasco et al., 1993; Ayyat et al., 1995;

Table 2
Number of animals and records for maternal performance traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>No. of records</th>
<th>No. of base animals</th>
<th>No. of sires*</th>
<th>No. of dams*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total litter size born</td>
<td>1118</td>
<td>80</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter size born alive</td>
<td>1120</td>
<td>80</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter size at 21 days</td>
<td>1053</td>
<td>79</td>
<td>55</td>
<td>120</td>
</tr>
<tr>
<td>Litter size at 28 days (weaning)</td>
<td>1051</td>
<td>79</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter size at 84 days (marketing)</td>
<td>1036</td>
<td>79</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter wt. at 21 days</td>
<td>1052</td>
<td>79</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter wt. at 28 days</td>
<td>1051</td>
<td>79</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>Litter wt. at 84 days</td>
<td>1036</td>
<td>79</td>
<td>55</td>
<td>121</td>
</tr>
</tbody>
</table>

* Number of sires and dams of litters. In addition, there were 56 maternal grand-sires and 108 maternal grand-dams of litters.
### Table 3
Estimates of heritability, permanent effects, and repeatability for maternal performance traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Statistic(^2)</th>
<th>(\hat{h}^2) ± S.E.</th>
<th>(\hat{p}^2) ± S.E.</th>
<th>(R)</th>
<th>(\sigma_{SP}^2) ± S.E.</th>
<th>(\sigma_{SP})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total litter size born</td>
<td></td>
<td>0.09 ± 0.07</td>
<td>0.22 ± 0.06**</td>
<td>0.30</td>
<td>0.02 ± 0.02</td>
<td>1.85</td>
</tr>
<tr>
<td>Litter size born alive</td>
<td></td>
<td>0.12 ± 0.07</td>
<td>0.21 ± 0.07*</td>
<td>0.32</td>
<td>0.01 ± 0.01</td>
<td>1.90</td>
</tr>
<tr>
<td>Litter size at 21 days</td>
<td></td>
<td>0.06 ± 0.07</td>
<td>0.20 ± 0.07*</td>
<td>0.26</td>
<td>0.02 ± 0.02</td>
<td>1.75</td>
</tr>
<tr>
<td>Litter size at 28 days (weaning)</td>
<td></td>
<td>0.09 ± 0.07</td>
<td>0.16 ± 0.07*</td>
<td>0.25</td>
<td>0.01 ± 0.02</td>
<td>1.73</td>
</tr>
<tr>
<td>Litter size at 84 days (marketing)</td>
<td></td>
<td>0.07 ± 0.06</td>
<td>0.12 ± 0.06*</td>
<td>0.19</td>
<td>0.03 ± 0.02</td>
<td>1.72</td>
</tr>
<tr>
<td>Litter wt. at 21 days, (g^a)</td>
<td></td>
<td>0.08 ± 0.06</td>
<td>0.10 ± 0.05*</td>
<td>0.18</td>
<td>0.10 ± 0.03**</td>
<td>198.09</td>
</tr>
<tr>
<td>Litter wt. at 28 days, (g^a)</td>
<td></td>
<td>0.09 ± 0.06</td>
<td>0.10 ± 0.06</td>
<td>0.19</td>
<td>0.08 ± 0.03*</td>
<td>260.95</td>
</tr>
<tr>
<td>Litter wt. at 84 days, (g^b)</td>
<td></td>
<td>0.02 ± 0.04</td>
<td>0.06 ± 0.04</td>
<td>0.09</td>
<td>0.03 ± 0.02</td>
<td>901.90</td>
</tr>
</tbody>
</table>

\(^a\) \(\hat{h}^2\), heritability (additive genetic variance as a proportion of phenotypic variance); \(\hat{p}^2\), permanent effects (non-additive genetic plus permanent environmental effects variance as a proportion of phenotypic variance); \(R\), repeatability (sum of \(\hat{h}^2\) and \(\hat{p}^2\)); \(\sigma_{SP}^2\), variance due to random effect of service sire; \(\sigma_{SP}\), phenotypic standard deviation.

\(^b\) Adjusted for linear covariate of litter size at the corresponding age.

\(*P<0.05; **P<0.01."

Blasco, 1996; Lukefahr et al., 1996a; Lukefahr and Hamilton, 1997; Rochambeau, 1997). Low heritability of litter size is further reflected in low response to direct selection (=0.11 rabbits per litter per generation; Baselga et al., 1992; Pujardieu et al., 1994; Rochambeau et al., 1994; Gomez et al., 1996). However, other studies (Mgheni and Christensen, 1985; Khalil et al., 1987, 1988; Krogmeier et al., 1994) reported moderate to high heritability values, but these estimates were associated with rather high standard errors.

Maternal heritability values for litter weight at 21 days, 28 days, and 84 days were 0.08, 0.09, and 0.02, respectively. These estimates are in the range of heritability estimates (0.03 to 0.57) for litter weight at weaning (Garcia et al., 1980; Khalil et al., 1987; Johnson et al., 1988; Moura et al., 1991; Ferraz et al., 1992; Panella et al., 1992; Krogmeier et al., 1994; Ayyat et al., 1995). Litter weight at 84 days, having the lowest maternal heritability of 0.02, may best be explained by the expected increasing importance of the genetic contribution of the progeny in conjunction with the diminishing influence of the dam. It is also possible that a negative covariance between direct and maternal genetic effects may explain the low heritability. McNitt and Lukefahr (1996) reported a negative correlation of 0.12 between direct and maternal genetic effects for post-weaning average daily gain in New Zealand White rabbits.

In other tropical environments, for example, in Tanzania, Mgheni and Christensen (1985) reported realised heritability of 0.19 for 112-day body weight from a two-way selection experiment for litter size; in Ghana, heritability for individual fryer body weight at 90 days was 0.42 (Lukefahr et al., 1992); and in Hawaii, heritability for 56 to 84 days average daily gain was 0.48 (Moura et al., 1997). In Brazil, Ferraz and Eler (1994) reported direct heritabilities of 0.26 and 0.17 for individual body weight at 11 weeks of age in New Zealand White and Californian fryers, whereas maternal heritabilities were 0.00 and 0.08, respectively. Unfortunately, in the present experiment, individual fryer 84-day body weight records were not available to provide an estimate of direct heritability.

#### 3.2. Repeatability estimates for maternal performance traits

Repeatabilities for litter size at various ages were generally moderate, ranging from 0.19 for litter size at 84 days to 0.32 for litter size born alive (Table 3). There was a slight tendency for repeatability of litter size to decline with age of the litter. Repeatability values for litter size in this study tended to be close to or above the maximum of the range of values reported in the literature from temperate as well as tropical environments.
tropical rabbit populations (Donal, 1973; Rouvier et al., 1973; Suh et al., 1978; Garcia et al., 1982; Lukefahr et al., 1983a,b, 1984; Lahiri, 1984; Khalil and Affi, 1986; Khalil et al., 1988; Moura et al., 1991; Affi et al., 1992; Khalil, 1994; Ayyat et al., 1995; Lukefahr and Hamilton, 1997).

The estimates of repeatability for litter weight at various ages ranged from low (0.09 for litter weight at 84 days) to moderate (0.19 for litter weight at 28 days), being relatively lower than those estimates for litter size (Table 3). In contrast, Affi et al. (1992) reported that repeatability for litter weight at various ages was relatively higher than that for litter size. This contrast may be explained in part due to differences in statistical methodology, being more up to date in this study, and in part due to differences in population, being more heterogeneous in this study compared to New Zealand White and Californian breeds involved in the report by Affi et al. (1992). Repeatabilities of litter weights in this study were somewhat lower than values reported in the literature (Rouvier et al., 1973; Garcia et al., 1982; Lukefahr et al., 1983a,b, 1984, 1996b; Lahiri, 1984; Moura et al., 1991; Affi et al., 1992; Ferraz et al., 1992; Khalil, 1994; Ayyat et al., 1995; Lukefahr and Hamilton, 1997) for reasons that cannot be explained.

Results from our investigation certainly warrant further research. In other tropical environments, higher direct heritabilities for individual fryer and litter traits have been reported than those from temperate countries. If true, this may be attributable, in part, to the relatively more heterogeneous nature of rabbit populations in tropical environments. Nonetheless, the challenging environment indeed offers opportunities to genetically characterize rabbit populations to help determine appropriate breeding programmes to meet farmer’s demand for quality breeding stock.

References


