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GENETIC AND ENVIRONMENTAL TRENDS FOR POST-WEANING BODY WEIGHTS IN NEW ZEALAND WHITE AND Z-LINE RABBITS USING THE ANIMAL MODEL APPROACH

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Genetic and environmental trends were evaluated for post-weaning body weights of 20677 weaned rabbits of New Zealand White (NZW) and Z-line born between 1982 and 1996 from 1212 sires and 3168 dams. Multi-trait animal model was used for such evaluation taking into account body weights at 8 and 12 weeks of age. Heritability estimates for the two body weights in NZW were higher than those in Z-line; being 0.34 and 0.30 in NZW and 0.10 and 0.25 in Z-line at 8 and 12 weeks of age, respectively. Common litter effects were higher in Z-line (averaged 37.65%) than those in NZW (averaged 29.95%). All correlations between the two body weights were moderate or high; being 0.73 and 0.69 for genetic correlations, 0.60 and 0.64 for phenotypic correlations, 0.49 and 0.64 for common-litter correlations and 0.45 and 0.68 for environmental correlations in NZW and Z-line rabbits, respectively. The ranges in predicted breeding values (PBV) for body weights at 8 and 12 weeks of age were 572 and 639 gram in NZW, while they were 216 and 449 gram in Z-line, respectively; i.e. wide variations in PBV of body weights between the two strains were in favour of NZW rabbits. The accuracies ($r_{a\hat{a}}$) of minimum and maximum estimates of PBV were mostly higher in NZW than those in Z-line for the two weights; ranging from 0.48 to 0.73 in NZW and 0.38 to 0.62 in Z-line. Genetic trends indicate that PBV were mostly positive in NZW and negative in Z-line over the whole period of the study. In NZW rabbits, the trend indicates that the plateau for the breeding values reached soon at the beginning years, while in Z-line the rates of change in breeding values were very low during the six years of the study. Plots of year-season trends indicate that environmental effects (i.e. seasonal-annual variations) play a large role in improvement of the two body weights in both lines.

Key words: Rabbits, Body weights, Animal model approach, Heritability, Correlations, Breeding values, Genetic trend.

When a control population is not available, animal model methodology can be useful for estimating genetic and environmental trends of a selection process (Henderson, 1984). In development and evaluation of breeding programs in rabbits, both genetic parameters (e.g. heritability and predicted breeding values) and genetic trends need to be evaluated accurately. Compared to other livestock species, few estimates have been reported on rabbits for genetic and environmental trends. The importance and use of genetic parameters to improve the productivity in rabbits was discussed earlier by Khalil et al. (1986) and Lukefahr (1988). In rabbits, maternal or litter influences may be more important than additive genetic effects for post-weaning growth (Ferraz et al., 1992). Based on paternal half sibs, El-Raffa (1994) have estimated the genetic parameters for some productive and reproductive traits in **NZW** and **Z**-line rabbits raised in the same rabbitry of the present study. Nevertheless, no genetic analysis has been done yet to estimate the genetic and environmental trends for these traits based on new methodology of analysis (e.g. **MTDFREML, PEST, MTGSAM**, ...etc). Therefore, the main objectives of this work were: (1) To estimate genetic parameters (e.g. direct additive genetic, common litter effect and error variances as well as heritability) for body weights at 8 and 12 weeks of age in New Zealand White and Z-line rabbits, (2) To predict the breeding values for the two weights under the study, and (3) To evaluate the genetic and environmental trends for the two body weights over several generations.

MATERIALS AND METHODS

Data used in the present study represent 20677 weaned rabbits of New Zealand White (**NZW**) and **Z**-line born between 1982 and 1996 from 1212 sires and 3168 dams in the nucleus breeding farm named ZIKA (Schweizerhof, Untergroeningen, Germany). **Z**-line was originated from mating various local German strains together (synthetic line). Both lines were selected for some productive and reproductive performances as reported by El-Raffa (1994).

During the whole period of the investigation (15 years for **NZW** and six years for **Z**-line), the rabbits were housed in windowed environmentally controlled rabbitry. A minimum temperature of 14^0C was maintained during winter (optimum 18^0C). The relative humidity was 60% ± 10%. Brood spectrum fluorescent bulbs 4 watt/m^2 were used to provide 14 hours light per day. Manure was collected in deep pits and removed twice a week in winter and three times per week in summer.

The young rabbits were weaned at 28 days of age and then removed from the does' cages, ear tagged and raised in collecting cages in groups of eight rabbits before eight weeks of age and four rabbits per cage thereafter. Breeding animals and their progenies were fed ***ad libitum*** pelleted ration, in which minimum rate of crude protein was 16% and maximum rate of crude fiber was 14%. Water was available continuously.

Models of analysis and estimation of variance components:

Individual body weight at 8 and 12 weeks of age for 9624 and 6673 rabbits were recorded in **NZW** and **Z**-line, respectively. Data of each line were analysed separately using multi-trait animal model (Boldman et al, 1995). Variances and covariances obtained by **REML** method of **VARCOMP** procedure (SAS, 1996) were used as starting values (guessed values) for the estimation of variance and covariance components. The structure of the data analyzed is shown in Table 1. The following animal model was used:

$$y = Xb + Z_a u_a + Z_c u_c + e$$

where y= Vector of observations on animal; b= Vector of fixed effects of sex and year-season (57 levels for **NZW** and 22 levels for **Z**-line); u_a= Vector of random additive genetic effect of the animal for the i^th^ trait; u_c= Vector of random common litter effect (dam x litter size at birth x parity combination); e= Vector of random error; X, Z_a and Z_c are incidence matrices relating records of i^{th} trait to the fixed effects (sex and year-season), random animal effects and random common litter effects, respectively.

All estimates of **BLUP** were derived by multi-trait animal model (**MTAM**) using the **MTDFREML** program (Boldman et al., 1995) adapted to use the sparse matrix package, **SPARSPAK** (George and Ng, 1984). The **MTAM** was considering the relationship coefficient matrix ($\mathbf{A}^{-1}$) among animals in estimation (Korhonen, 1996). Convergence was assumed when the variance of the log-likelihood values in the simplex reached $<10^{-9}$. Occurrence of local maxima was checked by repeatedly restarting the analyses until the log-likelihood did not change beyond the first decimal. The **MTAM** was used to estimate direct additive genetic, common litter effect, error, phenotypic variances and heritability. Heritability (h^2a) was computed as:

$$h_a^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_c^2 + \sigma_e^2}$$

where σ_a^2, σ_c^2 and σ_e^2 are the variances due to effects of direct additive genetic, common litter and random error, respectively.

Prediction of breeding values (PBV):

The variances and covariances estimated by **MTAM** analysis were used for prediction of breeding values, standard errors and accuracies of predictions ($r_{a\hat{a}}$). Solutions for equations of animals were computed from the pedigree file, one animal at a time for animals with records and animals without records (sires and dams). A diagonal element ($\mathbf{d}_t$) and an adjusted right-hand side (y^*_t) were accumulated with each pedigree file record for the t^{th} animal. For animal with and without records, the formula used to estimate the **PBV** was (Kennedy, 1989): **PBV** = $[y^*_t/\mathbf{d}_t]$; where $y^*_t/\mathbf{d}_t$ = breeding values of the animals.

Table 1. Structure of the data analyzed in New Zealand White and Z-line rabbits

Item	New Zealand White	Z-line
No. of sires	683	529
No. of dams	1717	1451
No. of animals weaned	9624	6673
Total number of animals in the pedigree file	12024	8653

The accuracy of **PBV** for each individual was estimated according to Henderson (1975) as:

$$r_{A\hat{A}} = \sqrt{1+F_j - d_j\alpha_a}$$

where $r_{A\hat{A}}$= the accuracy of prediction of the ith animal's breeding value; F_j= inbreeding coefficient of animals (assumed equal to be zero); d_j= the jth diagonal element of inverse of the appropriate block coefficient matrix; and $\alpha_a = \sigma^2_e/\sigma^2_a$.
Standard errors of predicted breeding values ($s.e._p$) were estimated for each individual as: $s.e._p = d_j\sigma^2_e$; where d_j and σ^2_e were defined before.

Genetic and environmental trends:

The averages of **PBV** and the estimates of year-season effects were regressed on year-season factor to analyse the general trends of these values (Garreau et al., 2000). These values were plotted for **NZW** and Z-line rabbits separately to illustrate the seasonal-annual genetic and environmental trends for the two body weights under the study.

RESULTS AND DISCUSSION

Means and phenotypic standard deviations of post-weaning body weights at 8 and 12 weeks of age were presented in Table 2 to characterize the two populations of rabbits under the study.

Table 2. Means, standard deviations (SD) and coefficients of variation (V%) for body weights at 8 and 12 weeks of age in New Zealand White and Z-line rabbits

Body weight	New Zealand White				Z-line			
	No.	Mean	SD	V%	No.	Mean	SD	V%
At 8 weeks (**BW8**)	9624	1581	200	12.6	6673	1604	230	14.3
At 12 weeks (**BW12**)	9624	2402	233	9.7	6673	2578	254	9.9

Genetic parameters:

Variance components [direct additive genetic (σ_a^2), common litter effect (σ_c^2), error (σ_e^2) and phenotypic (σ_p^2)] and heritabilities for body weights in **NZW** and **Z**-line rabbits are presented in Table 3. The estimates for body weights at 8 and 12 weeks of age showed that **NZW** rabbits had higher additive genetic variance (averaged 31.7%) comparable to **Z**-line (averaged 17.4%). This indicates that improvement of body weights in **NZW** could be possible through selection. The percentage of direct additive genetic variance in **NWZ** was higher at younger age (8 weeks) than at older age (12 week). Mostageer et al. (1970) and Khalil et al. (1987) showed the same trend. Conversely, **Z**-line had lower additive genetic variance at younger age (8 weeks) than at older age (12 weeks). This may be due to high non-additive genetic effects (common litter effects) at 8 weeks than at 12 weeks, which are quite agreeable with Su et al. (1999). Reviewed percentages of variance for post-weaning body weights estimated by **REML** method show that contribution of sire was generally low or moderate (Lukefahr et al, 1992; El-Raffa, 1994; Hassan, 1995); estimates ranging from 3.77 to 13.01%.

Variances of common litter effect (σ_c^2) in **NZW** (averaged 29.95%) were lower than in **Z**-line (averaged 37.65%) for the two body weights (Table 3). In both strains, estimates of σ_c^2 were the highest for body weight at 8 weeks, which reflect that maternal and/or common environmental effects were large since individuals in the same litter being nursed by the same dam and reared in the same cage. This is quite agreeable with Khalil et al. (1987), Ferraz et al. (1991), Ferraz et al. (1992) and McNitt and Lukefahr (1993). Su et al. (1999) found that percentage of σ_c^2 was 60% for daily litter gain during the period from one to 35 days of age in Danish White rabbits. Estimates of σ_c^2 for body weight at 12 weeks in **NZW** and **Z**-line were reduced by 26.4% and 44.7% than that for body weight at 8 weeks, respectively. These results showed a rapid reduction of maternal and/or common environmental effect with the advancement of the rabbits' age.

Heritability estimates (h_a^2) for body weight at 12 weeks were moderate in both strains, while at the early age of 8 weeks they were low in **Z**-line and moderate in **NZW** (Table 3). The estimates were 0.34 and 0.30 in **NZW** and 0.10 and 0.25 in **Z**-line for body weights at 8 and 12 weeks, respectively. The differences in heritability estimates for the two body weights of the two strains could possibly due to variations in genetic make up of the strain (El-Raffa, 1994). Esteny et al. (1992) and Ferraz et al. (1992) reported heritabilities of 0.17 and 0.08 for body weight at 77 days using mixed model procedure, respectively. Based on paternal half sibs' analysis, Bharat and Ahlawat (1999) reported heritability estimate of 0.34 for body weight at 12 weeks. Also, Enab (2001) found that heritabilities for body weight at 8 and 12 weeks of age were 0.31 and 0.30, respectively. Using an animal model, Khalil et al. (2000)

obtained heritability estimates of 0.090 and 0.256 for body weights at 8 and 12 weeks of age, respectively.

Table 3. Variances components estimates [direct additive genetic (σ_a^2), common litter effect (σ_c^2), error (σ_e^2) and phenotypic (σ_p^2)], heritabilities (h_a^2), genetic correlations (r_G), common litter correlations (r_C), environmental correlations (r_E) and phenotypic correlations (r_P) for the two body weights in New Zealand White and Z-line rabbits

Trait+	σ_a^2	%	σ_c^2	%	σ_e^2	%	σ_p^2	h_a^2	r_G	r_C	r_E	r_P
New Zealand White:												
BW8	12019	33.7	12312	34.5	11367	31.8	35699	0.34	0.73	0.49	0.45	0.60
BW12	15244	29.6	13082	25.4	23236	45.1	51561	0.30				
Z-line:												
BW8	4783	9.8	23806	48.5	20483	41.7	49072	0.10	0.69	0.64	0.68	0.64
BW12	13979	24.9	15056	26.8	27129	48.3	56165	0.25				

Estimates of genetic (r_G) and phenotypic (r_P) correlations between the two body weights at 8 and 12 weeks were high and positive in both strains (Table 3). Estimates of r_G were 0.73 and 0.69 in **NZW** and Z-line, respectively. These estimates fall within the range of literature (El-Maghawry, 1990; Khalil et al., 1993). Bharat and Ahlawat (1999) reported similar estimate of 0.70 for r_G between body weights at 8 and 12 weeks. Estimates of common litter (r_C) and environmental (r_E) correlations between the two weights were moderate (0.49 and 0.45) in **NZW** and high (0.64 and 0.68) in Z-line rabbits (Table 3). These results showed the importance of common litter effect on post-weaning body weights in rabbits. Estimates of r_C are not available in the literature for comparison here since most of the models used were not involved such important litter effect in rabbits.

Predicted breeding values (PBV):

Estimates of minimum and maximum predicted breeding values (**PBV**) and their accuracies for body weights in **NZW** and Z-line are given in Table 4. The **PBV** for body weight at 8 and 12 weeks of age ranged from –269 to 303 gram and from –315 to 324 gram in **NZW**, respectively, while they ranged from –97 to 119 gram and from –215 to 234 gram for the same order in Z-line. This indicates that additive genetic effects for body weights in **NZW** were higher than in Z-line. Using a sire model, Shebl et al. (1997) with data of three lines of rabbits raised in Germany (N-line originated from New Zealand White, Z-line originated from mating various local German strains, and **G** line was developed from Giant breed), ranges in **PBV** of post-weaning body weights at 8, 12 and 16 weeks of age in G line were the largest, followed by N-line and

Table 4. Minimum, maximum and ranges of predicted breeding values (PBV) and standard errors (SE) and accuracy of prediction ($r_{A\hat{A}}$) for the two body weights in New Zealand White and Z-line rabbits with records estimated by multi-trait animal model

Trait	Minimum			Maximum			Range in PBV
	PBV	SE	$r_{A\hat{A}}$	PBV	SE	$r_{A\hat{A}}$	
New Zealand White:							
BW8	-269	74.8	0.51	303	94.5	0.73	572
BW12	-315	86.9	0.48	324	108.2	0.71	639
Z-line:							
BW8	-97	64.1	0.38	119	61.1	0.47	216
BW12	-215	94.5	0.60	234	93.2	0.62	449

Z-line. In this study, the ranges in **PBV** in **N**, **Z** and **G** lines, respectively were 267, 253 and 473 gram for 8-week weight, 341, 280 and 488 gram for 12-week weight, and 304, 99 and 542 gram for 16-week weight. Using an animal model methodology, Hassan (1995) reported that the breeding values for weaning weight of **NZW** rabbits raised in Egypt ranged from – 156 to 180 grams, while Khalil et al. (2000) reported ranges of 286.6, 330.6, 212.4, 145.6 and 236.4 grams at 5, 6, 8, 10 and 12 weeks of age, respectively.

The accuracies ($r_{a\hat{a}}$) of minimum and maximum estimates of **PBV** were mostly higher in **NZW** than those in **Z**-line for the two weights (Table 4). This may be due to that estimates of heritability in **NZW** were high associated with more available pedigree information for all individuals (Korhonen, 1996; Bourdon, 1997). In general, Korhonen (1996) reported that if the sire has not yet progeny in evaluation, the reliability of the index is approximate 40%, but if the number of progeny is over 200, the reliability is over 90%.

Genetic trend:

Genetic and environmental trends for the two body weights in **NZW** and **Z**-line are shown in Figures 1 up to 4.

For **NZW** rabbits, genetic trends in Figures 1&2 indicate that **PBV** were mostly positive, but the plots indicate that the plateau reached soon at the beginning years of the study. Generally, genetic gains for body weights in **NZW** were low over the whole 15 years of the study compared to results of Estany et al. (1992) and Lukefahr et al. (1996). This could be explained on the basis of reproductive traits has been used as secondary selection criteria over the years of improvement (El-Raffa, 1994). Even if the genetic correlations between reproductive and growth traits are not strongly unfavorable, the addition of secondary selection criterion have reduced the efficiency of selection for growth traits in rabbits (Garreau et al., 2000).

Figure 1: Genetic and year-season effect trends for body weight at 8 weeks of age in NZW rabbits.

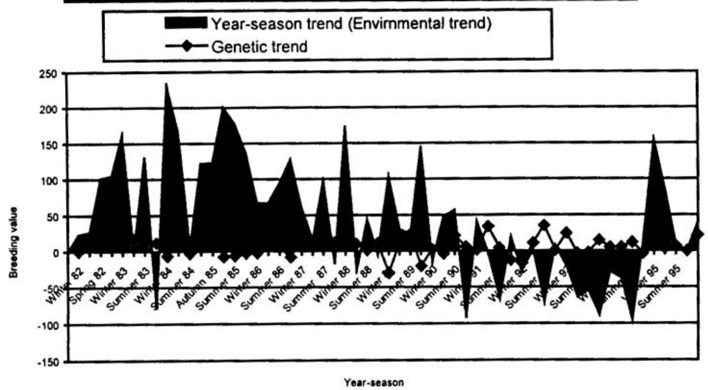


Figure 2: Genetic and year-season effect trends for body weight at 12 weeks of age in NZW rabbits.

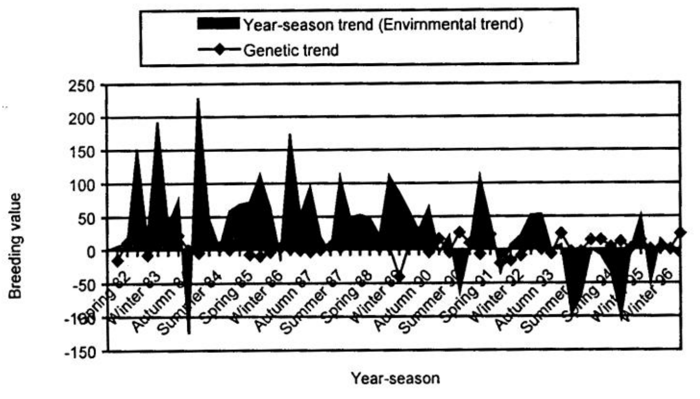


Figure 3: Genetic and year-season effect trends for body weight at 8 weeks of age in Z-line rabbits.

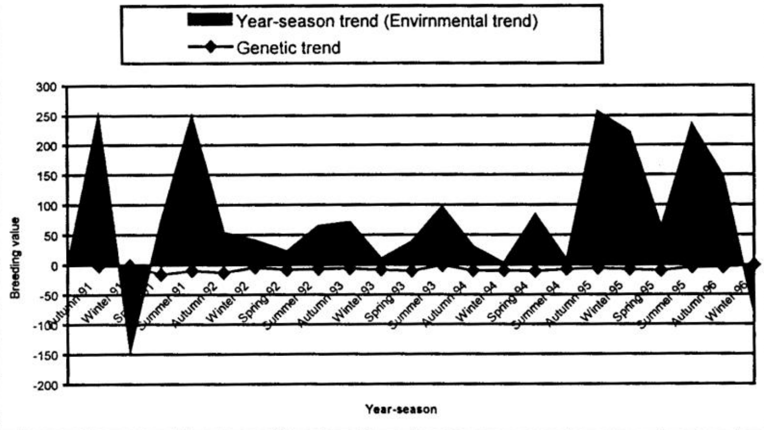
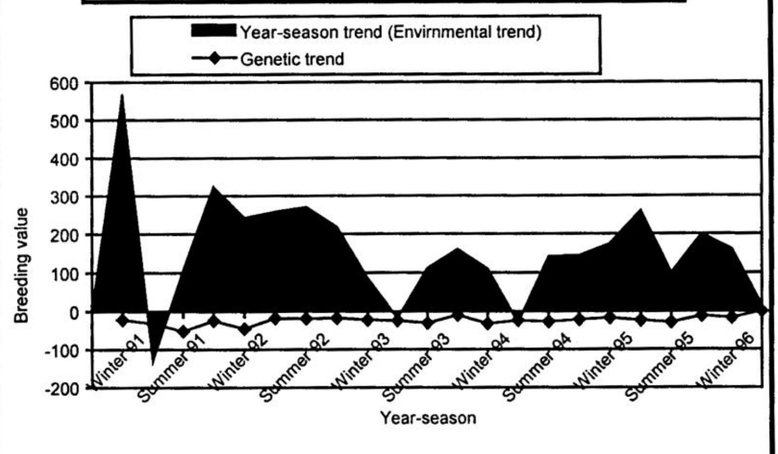


Figure 4: Genetic and year-season effect trends for body weight at 12 weeks of age in Z-line rabbits.



For **Z**-line rabbits, rates of change in genetic values were very low during the six years of the study (Figures 3&4). Plots in Figures 3&4 show that average of the genetic values was negative over the whole period of the study and therefore no genetic gain occurred for body weights in this line due to selection. This negative trend could be due to that **Z**-line is a synthetic line and most of the improvement happened in post-weaning growth may be due to an improvement in environmental conditions such as nutrient composition of the diet and management (El-Raffa, 1994). The improvement in growth performances during the formation of Pannon White breed in Solovania was due to an improvement in genetic make-up and the environmental conditions as well (Szendroe et al, 1998). The changes in nutrient composition of the diet may have contributed to an improvement in breeding conditions during the formation of such breed. Ferraz et al. (1992) reported that average estimates of PBV were not regressed on year because the variation in changes from year to year might be due to some monitor effects such as changes in management or disease out breaks.

Environmental trend:

The plots indicate that year-season trends were positive and high in magnitude during the period from 1982 to 1989 for the two body weights in **NZW** (Figures 1&2). At the period from 1989 to 1996, the year-season trend fluctuated down and converted to show a negative trend thereafter. The trends for year-season effect on the two body weights in **Z**-line were positive and high during the period from 1991 to 1996 (Figures 3&4). This indicated that environmental effects play a large role in improvement of body weights in both strains. The phenotypic improvement presented by Szendroe et al (1998) between 1992 to 1996 was so mainly due to the improvement in husbandry. On the other hand, trends of year-season effect in the present study fluctuated high during 1991 and fluctuated down during the period of 1992 and 1993 and returned to fluctuate high thereafter for body weight at 8 weeks of age.

CONCLUSIONS

(1) In **Z**-line rabbits, because of lack of direct additive genetic variation and the substantial dam and non-additive genetic effects for post-weaning growth characteristics management and culling strategies should be based on the estimated producing ability. Conversely in New Zealand White rabbits, selection for post-weaning growth should concentrate on the breeding values of the individuals themselves (McNitt and Lukefahr, 1996).

(2) Estimates of genetic parameter obtained in the present study using multi-trait animal model seem to be the most accurate since the relationships among all animals as well as common litter effect were considered (Henderson, 1984; Lukefahr et al., 1996). Therefore, common litter effect must be considered in the models of analysis for post-weaning growth traits in rabbits to obtain unbiased estimates of heritability and breeding values and to plot the genetic and environmental trends accurately.

(3) Wide variations between the two strains under the study in predicted breeding values for body weight at 8 weeks of age might be an encouraging factor to improve body weight of this population of New Zealand White through selection.

(4) The multi-trait animal model methodology used was useful not only for predicting the breeding values, but in evaluating the genetic and environmental trends of these two populations of rabbits raised in intensive system of production.

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