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Genetic trends of laying merit in maternal (M55) and paternal (V44) strains of hens

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The purpose of the study was to evaluate with BLUP the effectiveness of breeding work performed in a commercial farm of laying hens where the selection index approach was applied. Production results of two (maternal M55 and paternal V44) nucleus strains regarded nine generations (1994-2002). Considered were body weight at the age of 18 weeks (BW), age (days) at first egg (MAT), number of eggs laid during first 15 weeks (IL), mean egg weight at week 10 of laying (EW), number of eggs laid during 44 weeks (L44) and hatchability (HA). Mean inbreeding coefficient of inbred birds amounted to 1.7 and 2.2%, in M55 and V44, respectively. Estimates of h^2 (REML with animal model) were found similar in both strains, being highest for BW (0.604 and 0.646) and EW (0.536 and 0.607) and lowest for IL (0.180 and 0.185 in M55 and V44, respectively). Annual genetic changes (BLUP) were: 0.69 and 0.54 eggs for IL, 2.64 and 2.23 eggs for L44, -0.62 and -0.79 days for MAT, –0.09 and 0.16 g for EW, respectively for M55 and A44 strains.

KEY WORDS: BLUP / genetic trends / laying hens / REML /selection index

In commercial egg production used are crosses of specialized purebred strains of laying hens. Thus, the main breeding (improvement) work is done within the purebred lines and only rarely the information on crossbreds' performance is used for evaluation of purebreds. The basic selection tool used in the Polish populations of laying hens is SELEKT system [Wężyk 1978] based on Hazel's [1943] selection index theory. It is a one-trait index using full- and half-sib information within a single generation. The traits evaluated are body weight, age at first egg, initial laying, laying rate and egg weight. In fact, one can think of other economically crucial traits, like hatchability or overall egg production. However, limiting oneself to one-generation information renders it impossible to estimate the progress resulting from selection applied. Yet, the results of multiple generations' selection are of great value to the breeders and producers [Savas et *al*. 1999, Bednarczyk *et al*. 2000, Szwaczkowski *et al*. 2000]. Ever since 1995 an electronic system of performance and pedigree recording has been employed in the Centre for Nucleus Breeding "MESSA" Ltd., Mienia, Poland. Thanks to the system reliable data bases have been established which have enabled applying the REML/BLUP with animal model approach to estimate genetic trends and, thus, to verify the effectiveness of the breeding work.

The purpose of this study was to trace back, using REML/BLUP with animal model, the response to selection performed with the selection index method.

Material and methods

The performance and pedigree data covered the years 1994-2002 inclusive, and regarded two synthetic strains of laying hens – Rhode Island White (M55) as maternal, and Rhode Island Red (V44) as paternal strain, with 35247 and 18527 performance-recorded hens, respectively. The numbers of birds and inbreeding coefficients (F_x) specific to each generation are presented in Table 1. The generation of 1994 year was set as basic. For all the hens body weight at week 18 of age (BW), age at first egg (MAT), number of eggs laid during first 15 weeks of laying (IL), and mean egg weight in week 10 of laying (EW) were recorded. Moreover, number of eggs laid during 44 weeks of laying (L44) and hatchability (HA) defined as the ratio of the number of eggs hatched over the number of eggs set, in three or four hatches for V44 and M55, respectively, were recorded in birds selected as parents of the next generation. The birds were maintained in a three-floor cage battery.

Variance components were estimated with REML using multiple-trait animal model, accounting for inbreeding. The breeding values were estimated with the BLUP procedure. In both cases the DMU computing package [Madsen and Jensen 2000] was used. The factors fitted in the statistical classifications are listed in Table 2.

The genetic trends were calculated using the BLUE solutions for years. The linear regression of the solution upon year (generation) measured the slope and significance of the trend.

Results and discussion

The number of birds identified in the pedigree and their inbreeding level are shown in Table 1. Raising of homozygosity and increasing numbers of inbred animals can be observed over the years 1994-2002. For the inbred birds (F_x>0) the mean F_x increased by

Table 1. Number of birds, number of inbred birds and mean inbreeding coefficient ($\overline{F}_x$) by generation and strain

Generation	Strain M55			Strain V44		
	number of birds		$\overline{F}_x$	number of birds		$\overline{F}_x$
	all	$F_x>0$		all	$F_x>0$	
1994	449	0	0	230	0	0
1995	4631	0	0	2226	0	0
1996	3863	0	0	2285	4	3.1
1997	3848	245	1.2	2233	140	1.4
1998	3942	2388	1.3	2415	1494	1.3
1999	4216	4039	1.1	2697	2647	1.5
2000	5003	5003	1.4	2295	2295	2.2
2001	5083	5083	2.0	2290	2290	2.7
2002	4934	4484	2.4	2279	2048	3.3
Total	35969	21242	1.7	18950	10918	2.2

Table 2. Effects fitted in models for particular traits

Effect	Type	BW	MAT	IL	EW	L44	HA
Hatch within year	fixed	x					
Year-hatch-floor	fixed		x	x	x	x	x
Days of initial laying	covariate			x			
Days of 44 weeks laying	covariate					x	
Number of eggs set	covariate						x
Additive genetic	random additive	x	x	x	x	x	x

BW – body weight at the age of 18 weeks.
MAT – age (days) at first egg.
IL – number of eggs laid during first 15 weeks of laying.
EW – mean egg weight at week 10 of laying.
L44 – number of eggs laid during 44 weeks of laying.
HA – hatchability.

some 2.4% in M55 and by 3.3% in V44 strain. In a similar study of Savas *et al.* [1999] the mean F_x reached 4.8% and 3.9% in commercial paternal and maternal lines of laying hens, over 10 generations. Although possible inbreeding depression can negatively affect the performance of purebreds, the expected benefits from outbreeding are the function of the number of crossbred chickens sold, and their price, hopefully reflecting their better quality due to heterosis. Still, the mating system should be monitored carefully to keep inbreeding at bay.

The results of variance components estimation are presented in Table 3 as heritability (h^2) and genetic correlation (r_G) coefficients between the traits investigated. The h^2 values are of similar magnitude in both strains and are located at the higher end of the estimators published by others [Wężyk *et al*. 1993, Poggenpoel *et al*. 1996,

Table 3 Estimated heritability coefficients (h^2, bolded) of traits studied and coefficients of genetic correlation (r_G) between them across seasons

Season	Trait	BTP		MLT		IL		DTP		L[illegible]		H[illegible]	
		h^2/r_G	SE	h^2/r_G	SE	h^2/r_G	SE	h^2/r_G	SE	h^2/r_G	SE	h^2/r_G	SE
[illegible]	BTP	**0.646**	0.014										
	MLT	-0.060	0.017	**0.457**	0.016								
	IL	-0.19[illegible]	0.016	-0.076	0.0[illegible]1	**0.185**	0.012						
	DTP	0.116	0.015	0.015	0.011	-0.196	0.019	**0.536**	0.017				
	L[illegible]	-0.189	0.05[illegible]	-0.01[illegible]	0.061	0.668	0.056	-0.171	0.060	**0.185**	0.035		
	H[illegible]	0.019	0.058	0.1[illegible]1	0.061	-0.105	0.078	-0.[illegible]	0.059	-0.111	101	**0.166**	0.036
[illegible]	BTP	**0.60[illegible]**	0.010										
	MLT	-0.18[illegible]	0.015	**0.503**	0.011								
	IL	-0.170	0.051	-0.001	0.056	**0.180**	0.016						
	DTP	0.198	0.011	0.151	0.017	-0.111	0.051	**0.607**	0.011				
	L[illegible]	-0.071	0.071	-0.190	0.079	0.67[illegible]	0.070	-0.111	0.07[illegible]	**0.13[illegible]**	0.037		
	H[illegible]	-0.19[illegible]	0.07[illegible]	0.066	0.081	0.101	0.099	-0.[illegible]81	0.071	0.177	0.111	**0.199**	0.0[illegible]5

SE – standard error

Trait symbols are explained at the bottom of Table 1

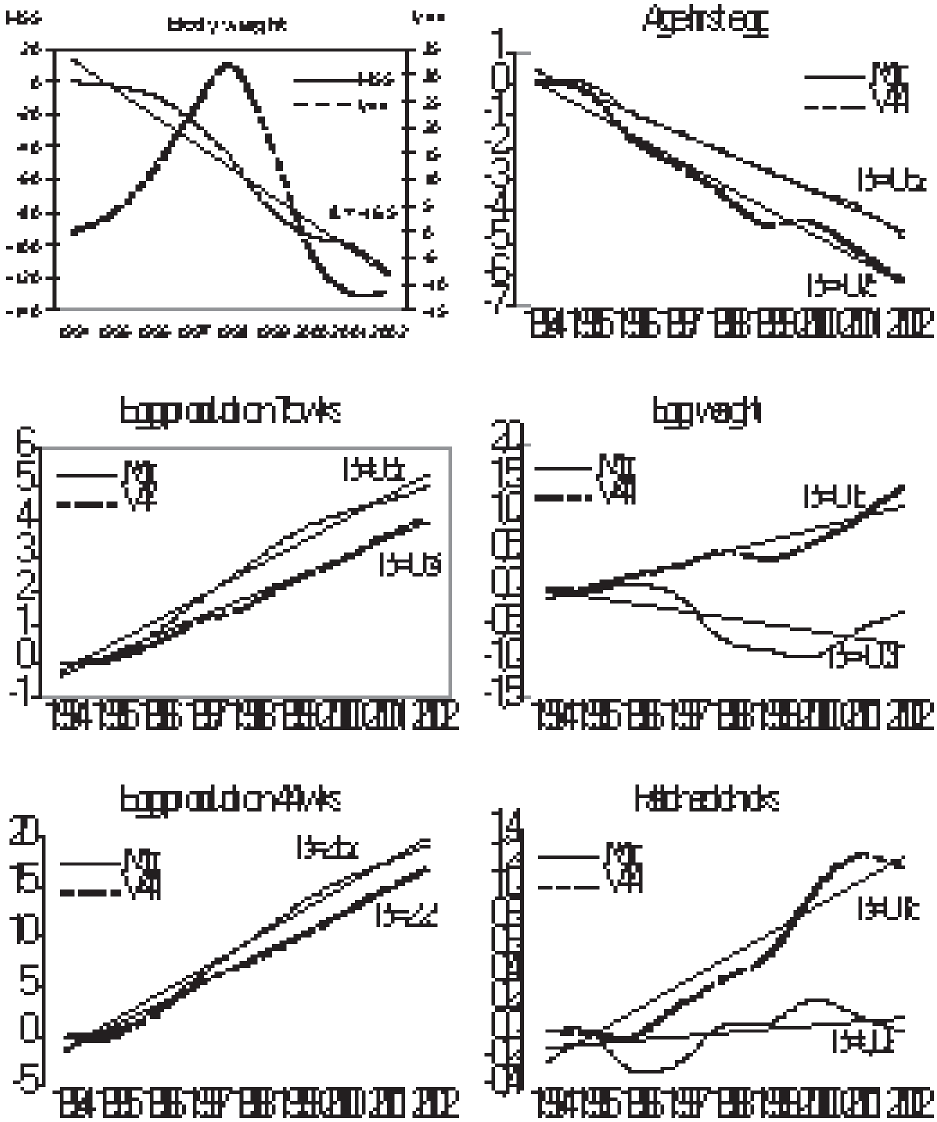

Fig. 1. Genetic trends of the traits examined, by strains.

Szwaczkowski 1999, Bednarczyk *et al*. 2000].

The genetic correlations (Tab. 3) reflect the common dilemma of having small, early maturing birds, lying many big eggs [Wężyk *et al*. 1993, Poggenpoel *et al*. 1996]. The strains, however, differed when correlations between hatchability and body weight or number of eggs laid were considered. In the maternal M55 hatchability did not depend on body weight (r_G = 0.019) while in the paternal V44 strain, high body weight tended to decrease the hatching rate (r_G/SE = -0.194/0.074). Negative r_G estimates between number of eggs laid (both initial laying and 44-weeks laying) and hatching rate in M55, and positive in V44 indicate a threshold at which stressed laying rate begins to deteriorate hatchability.

The genetic trends are expressed either as the actual curves or as linear approxima-

Table 4. [illegible] errors (SE) and significance levels

Trait	Strain M55		Strain V44	
	b	SE	b	SE
BW (g)	-16.46**	1.24	-2.13ns	1.94
MAT (days)	-0.62**	0.03	-0.79**	0.05
IL (no. of eggs)	0.69**	0.04	0.54**	0.03
EW (g)	-0.09*	0.04	0.16**	0.02
L44 (no. of eggs)	2.64**	0.12	2.23**	0.09
HA	0.03ns	0.02	0.18**	0.02

**P ≤ 0,01; *P ≤ 0,05; ns P > 0.05.
Trait symbols are explained at the bottom of Table 2.

tions (Fig. 1), or as regression coefficients of the slopes (Fig. 1, Tab. 4). The highest responses to selection in both strains were observed for numbers of eggs laid during first 15 and 44 weeks of laying. The latter was, in fact, a correlated response to selection for initial laying. Since the number of eggs laid is an obvious part of the laying merit, there are numerous reports on positive genetic gains in different populations [Pribylova and Pribyl 1991, Poggenpoel *et al*. 1996, Chung *et al*. 1999]. Comparison of the outcomes of selection reported for different strains may, however, be misleading without accounting for the selection differentials applied.

Similar genetic trends for number of eggs in M55 and V44 were accompanied by similar trends in pace of maturing. The age at first egg has dropped by 0.62 in M55, and by 0.79 a day per generation in V44. The higher response in V44, regardless smaller population size, may indicate more space left for improving this trait in the paternal line. In Leghorn populations such drop amounted to 0.27-2.33 days a year [Poggenpoel *et al*. 1996, Chung *et al*. 1999].

The changes of body weight, mean egg weight, and number of chicks hatched relative to the number of eggs set, brought about by selection, do not follow the pattern of the traits discussed above. It was decided in 1998 to change the breeding objective from increasing to decreasing body weight in V44. Nevertheless, body weight has decreased in both lines. The trends for egg weight showed different directions in the strains studied. While the mean egg weight increased by some 0.16 g a year in V44, a significant annual drop of 0.09 g was observed in M55. Again, despite smaller population size, it was possible to generate response to selection in the paternal line for a trait which is more an attribute of a maternal line. It is possible that the policy observed in the analysed flocks should change to restriction selection, and keep the egg weight constant in the maternal strain. Otherwise, the success achieved in the paternal strain can be additively counteracted by the maternal one, upon creating terminal crosses. The increase of egg weight reported in Leghorns was from 0.16 g to 0.82 g [Pribylova and Pribyl 1991, Poggenpoel *et al*. 1996, Chung *et al*. 1999]. In the present study the number of chicks hatched, relative to the number of eggs set, kept improving in the paternal strain, at a pace of 0.18 chicks a year, while is seems to have remained steady in the maternal strain, perhaps fulfilling criteria of restricted selection.

The egg producers require outbred birds of low body weight to decrease maintenance requirements, maturing early, and laying many, at least medium sized, eggs. This breeding objective seems to have been effectively realized in the flocks of Mienia, Poland, with the use of SELEKT system based on selection index. It is only possible to speculate what would have happened if more sophisticated methods like BLUP with animal model had been employed. It took, however, BLUP to enable generation analyses. Switching to more sophisticated methods of breeding value estimation is in store for all the breeding companies which want to be more competitive, even solely on the national market.

Since the actual production levels are kept confidential by the breeding companies it is difficult to compare the companies directly. The only way to compare production levels is, therefore, to use the results from testing stations, at which domestic and foreign, parental and commercial populations are tested. The outbred products of the strains studied are crosses Messa 445 and Messa 443, their respective performance data being published yearly, but exclusively in Polish [Gawęcki 2000, 2001]. The test of parental strains [Gawęcki 2000] revealed the birds to present the best survival rate over rearing and production periods; the hens were amongst the best layers of eggs of the highest hatching quality. In the test of terminal crosses [Gawęcki 2001] the birds showed highest survival rate during the rearing period, latest maturity, and one of the lowest egg production rates accompanied, however, by best food conversion and highest egg weight. It was also recommended, following egg quality analyses [Gawęcki 2001], to improve shell strength, white quality, and to decrease frequency of blood and meat spots.

Although the results of the presented analyses proved generally positive genetic trends obtained in the populations studied, it is concluded that further improvement of the laying merit requires switching to more effective methods of breeding value estimation, intentional accounting for relationships between selected traits, and including egg quality traits in the breeding goal. The competitiveness of the resulting terminal population may also require paying attention to the combining ability of the purebreds.

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Trendy genetyczne cech nieśności w ojcowskim i matczynym rodzie kur nieśnych

S t r e s z c z e n i e

Celem badań było zweryfikowanie za pomocą metody BLUP z modelem osobniczym, efektywności selekcji prowadzonej z wykorzystaniem systemu SELEKT, opartego na teorii indeksu selekcyjnego. Analizie genetycznej poddano wyniki użytkowości dziewięciu pokoleń (1994-2002) dwóch rodów zarodowych (matczynego M55 i ojcowskiego V44) komercyjnego stada kur nieśnych znoszących jaja o brązowej skorupie. Oceniano masę ciała w 18 tygodniu życia (BW), wiek osiągania dojrzałości płciowej (wiek zniesienia pierwszego jaja – MAT), liczbę jaj zniesionych przez pierwszych 15 tygodni nieśności (nieśność początkowa – IL), średnią masę jaja w 10 tygodniu nieśności (EW), liczbę zniesionych jaj w ciągu 44 tygodni (L44) i wylęgowość z jaj nałożonych (HA). Przeciętny współczynnik inbredu wśród osobników zinbredowanych wyniósł 1,7% (M55) i 2,2% (V44). Oszacowane odziedziczalności (REML z modelem osobniczym) przyjmowały zbliżone wartości w rodach, najwyższe dla BW (0,604–0,646) i EW (0,536-0,607), a najniższe dla IL (0,18-0,185). Średnie roczne zmiany wartości hodowlanej BLUP wynosiły: IL – 0,69 i 0,54; L44 – 2,64 i 2,23; MAT – -0,62 i -0,79; EW – -0,09 i 0,16, odpowiednio dla rodu M55 i V44.