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GENETIC AND PRODUCTION TRENDS IN NEW HAMPSHIRE LAYING HENS OVER 8 GENERATIONS

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Abstract. The aim of the study was to determine trends for genetic and production parameters in a population of New Hampshire N-11 laying hens over 8 generations. Individual performance testing included body weight at 33 weeks of age (g), egg weight at 30 weeks of age (g), age at puberty expressed as days of age at first egg (days), and number of eggs laid to 39 weeks of age. As a result of implementing the genetic improvement programme based on NOVASEL electronic data processing system, egg production was increased, age at first egg was advanced and body weight of the chickens decreased in the N-11 line. The analysis of estimates of effective population size (Ne) and coefficients of inbreeding (Fx) shows that the cockerel and hen mating system used for reproduction effectively protects the population from an increase in inbreeding.

Keywords: body weight, egg production, egg weight, laying hens, sexual maturity

INTRODUCTION

The principal objective of selective breeding is genetic improvement of economically important traits in successive generations. At present, the Polish programme for genetic improvement of laying hens covers the hen's body weight, egg weight, early puberty and initial egg production [Wężyk and Jankowski 2003]. The implementation of breeding programmes led to considerable advances in production and genetics. Egg production increased and the age at first egg was greatly advanced in Poland and around the world. Fairfull et al. [1998] report that over the last 50 years, egg production increased by 28% with the annual production progress of 1.8 egg per hen on average. At the same time, the total weight of eggs laid during the first year of production increased by 42.7% and mean egg weight by 11.7%, with 32% lower feed intake. This finding is in agreement with the results of research conducted over 20 years (1973–1993) at the Agricultural University in Kaposvár [Horn et al. 1997]. The results of a Polish study [Świerczewska et al. 2002] indicate that over a 20-year period, Tetra SL hens that lay brown-shelled eggs increased egg

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production by 25 eggs per layer (8.9%) with 10% better feed conversion, almost 18% lower average body weight, and earlier age at puberty. These successes result from the application of achievements in population genetics as well as broadly defined animal and veterinary sciences, especially those concerning the improvement of avian housing conditions, nutrition, lighting and prophylaxis [Albers and Sambeek 2002, Flock 2002].

In Poland, the pedigree breeding of native poultry species has been observed to decrease since 1999 [Wężyk and Cywa-Benko 2001]. This occurred as a result of intense competition in the marketing of breeding stock. Although the breeding stock offered by Polish farms is interesting in terms of genetics and production, they are unable to withstand competition from international breeding companies [Wencek 2007]. However, owning various lines of breeding stock offers great potential for Polish breeders to implement their own breeding ideas. There is a constant need to monitor the results of breeding work and to evaluate the genetic parameters of layer strains, including the population of New Hampshire N-11 hens. In Poland, the selective breeding of the strain imported from the Austrian Landesman company was begun in 1962. N-11 hens were initially kept at the Kowalskie State Farm and moved to the Poultry Selection Centre in Brodziszewo, from where they were brought to the Duszniki Farm. This strain was used in commercial crossbreeding to obtain parental groups for production of commercial layer hybrids known as Astra N, D and Experimental, characterized by good productivity.

The aim of the study was to determine trends in genetic and production parameters of New Hampshire N-11 laying hens over 8 generations.

MATERIAL AND METHODS

The population of New Hampshire laying hens of line N-11, subjected to genetic improvement in the years 2000/2001 to 2008/2009 (generations 1 to 8) at the Pedigree Layer Farm in Duszniki, was investigated. At 18 weeks of age, the birds were moved from the growing facility to the poultry house while retaining the numbers given in Table 1. Wright's formulas [1931] were used to calculate the effective population size (N_e), or the rate at which genes are eliminated as a result of random genetic drift, and the increase in flock homozygosity (F_x), which is inversely proportional to the effective population size.

Birds were reared under an intensive system in houses equipped with modern technological equipment Throughout rearing and production, birds received complete standard diets *ad libitum*. There were no epidemics or diseases during the study period. Birds were individually wing-banded with barcode tags. According to Bednarczyk et al. [1995], this system significantly limits the possibility of making errors during performance testing and makes the process less labour-consuming, thus increasing the effectiveness of the selection work.

Individual performance testing included body weight at 33 weeks of age (g), egg weight at 30 weeks of age (g), age at puberty (days), and number of eggs laid to 39 weeks of age. Production parameters were characterized using the generally accepted methods of mathematical statistics and population genetics. For each trait, means (x), standard deviations (SD) and coefficients of variation (V%) were calculated in lines and birth-year groups. Coefficients of heritability (h^2) were estimated using analysis of variation for each trait selected in a line. This farm is the only farm in Poland to carry out family selection based on NOVASEL electronic data processing system. Time trends were specified to determine the line's response to selection using linear regression equations. Statgraphics Plus 5.1 was used for every simple linear regression (significant at 0.05) to determine confidence limits and mean error of estimation (SE), which shows the degree to which individual observations depart from the trend line.

RESULTS AND DISCUSSION

Changes were found in the level of genetic parameters and production traits as a result of the genetic improvement programme for New Hampshire N-11 hens. Table 1 shows that the effective size of the analysed populations, dependent on the number of males (n = 35 to 50) and females (n = 205 to 340) ranged from N_e =124.49 to N_e = 174.36, which had a direct effect on the low level of inbreeding in the flocks (F_x = 0.29 – 0.40). The low inbreeding level of individual populations is influenced by the applied selection system, in which the mated cockerels and hens are at least two generations apart [Wężyk and Jankowski 2003]. In the present study, the F_x coefficients calculated for individual populations proved small, which means that the degree of homozygosity had no significant effect on productivity and the magnitude of estimated genetic parameters.

Table 1. Number of sires, mothers, daughter hens, effective population size (N_e) and coefficient of inbreeding (F_x%)
Tabela 1. Liczebność kogutów-ojców, kur-matek i kur-córek oraz kształtowanie się efektywnej liczebności populacji (N_e) oraz współczynnika inbredu (F_x%)

Generations Pokolenie	Number – Liczba			N_e	F_x
	sires ojców	mothers matek	daughters córek		
1	37	285	825	130.99	0.38
2	39	303	850	138.21	0.36
3	40	334	985	142.89	0.35
4	50	340	586	174.36	0.29
5	40	205	501	133.88	0.37
6	40	314	732	141.92	0.35
7	40	280	598	140.00	0.36
8	35	281	575	124.49	0.40
x	40	293	707	140.84	0.36

Analysis of data found in Table 2 and in Fig. 1 shows that the highest selection pressure (*w*) was placed on increased egg production (*w* = 0.7 – 0.9) and mean egg weight (*w* = 0.1 – 0.3), which had a direct effect on the traits that showed an upward trend with the increasing value of *w.* Mean egg weight ranged from 59.3 to 60.9 g with an upward trend and a low estimation error (SE = 0.45). The highest egg production (about 104 eggs per layer) and a positive trend, with SE = 9.65 were observed in generations 7 and 8, which is consistent with the direction of selection. As regards body weight, the negative selection pressure (w = –0.10) used in generations 6 and 7 caused it to decrease from 2501 g (generation 1) to 2169 g (generation 7). The decrease in hens' body weight and a clear response of the flock to selection is attributable to the relatively high heritability of this trait ($h^2 = 0.46 – 0.63$), which was also reported by Kuhn and Arthur [1999], Settar and Turkmunt [1998] and Calik [2009]. In addition, no negative trends were noted for egg weight, which is of great importance because a positive correlation between hen's body weight and egg weight has been reported in the literature [Calik 2002, Krawczyk 2006]. Genetic variation in body weight and the use of this trait in selection of laying hens were the subject of many studies [Leeson et al. 1997, Masso et al. 1998, Sewalem et al. 1998, Sharma et al. 1998, Bednarczyk et al. 2000, Singh et al. 2000, Calik 2002, Krawczyk 2006]. These authors found that hen's growth is a complex of traits shaped by genetic and environmental factors and is dependent on age. During rearing, a hen should grow rapidly to reach optimum body weight for its type at puberty. Therefore, layer-type pullets that come early into egg production should be characterized, prior to puberty, by a short non-productive and low-input period of rearing as well as rapid and rhythmic regulation of egg weight [Poggenpoel and Duckitt 1988, Sharma et al. 1998, Flock 2002]. A relationship between increased body weight of laying hens and decreased egg production and other components of reproductive ability were presented as a correlated consequence of selection for body weight by Siegel [1988], Shalev and Pasternak [1993], Sewalem et al. [1998], Singh et al. [2000] and Szwaczkowski et al. [2000]. It is thought that layer-type pullets that grow too fast may undergo an increase not only in muscle weight but also fatness, which may adversely affect ovarian function. Damme [2000] stress that under semi-intensive and extensive (backyard) systems the producer, in addition to production of eggs, wants to obtain a hen of good meat value at the end of egg production. In such a case, lines should be selected to maintain body weight at a certain level or even increase it, so as to produce commercial hybrids characterized not only by good egg production but also by good meat properties. This direction of selection may be particularly important when increasing the population of hens raised on litter and on free range.

The rate of breeding progress in laying hens is affected by ovulation rate and the mineral balance, which determine high productivity while maintaining proper physical condition and desirable egg content composition [Wężyk and Cywa-Benko 2001]. Thus, under certain environmental conditions, i.e. optimal nutrition, lighting, temperature and good health, many genes that primarily control egg production processes may act so as to allow the hen to manifest its genetic potential to the full. In addition, egg production is also dependent on age at puberty, number and length of individual clutches, and laying persistency [Besbes and Ducrocq 2003]. In pedigree flocks, egg production is determined using a short-term test that usually includes initial egg production during the first three months of lay. Because of a high correlation with other production traits, the introduction of initial egg production as an essential component of the selection index made it possible to reduce the number of traits included in the selection (McMillan et al. 1986). In the present study, egg production evaluated to 39 weeks of age was found to improve with heritability of h^2 = 0.22 – 0.36. According to many publications [Sewalem et al. 1998, Sharma et al. 1998, Kuhn and Arthur 1999, Anang et al. 2000, Hazary et al. 2000, Singh et al. 2000] and the present study, initial egg production shows a strong genetic, environmental and phenotypic correlation with early puberty. Therefore, initial egg production increases as a result of selection for accelerated puberty.

Table 2. Trends in selection pressure (w), productivity and coefficients of heritability (h^2)
Tabela 2. Kształtowanie się nacisków selekcyjnych (w), produkcyjności oraz współczynników odziedziczalności (h^2)

Trait – Cecha	Generations Pokolenie	w	i	$\overline{x}$	SD	V%	h^2_{SD}±SE
Body weight – BW, g Masa ciała – MC, g	1	0.00	–0.084	2501	227	9.08	0.51±0.12
	2	0.00	0.021	2553	244	9.56	0.49±0.13
	3	0.00	0.082	2403	218	9.07	0.46±0.11
	4	0.00	–0.022	2418	241	9.97	0.52±0.18
	5	0.00	0.011	2441	241	9.87	0.46±0.11
	6	–0.10	0.155	2365	187	7.91	0.51±0.15
	7	–0.10	0.109	2169	202	9.31	0.63±0.18
	8	0.00	–0.004	2294	164	7.14	0.38±0.15
Egg weight – EW, g Masa jaja – MJ, g	1	0.30	0.152	59.7	3.9	6.53	0.56±0.15
	2	0.20	0.188	59.5	3.9	6.55	0.41±0.13
	3	0.20	0.118	59.6	4.0	6.71	0.45±0.12
	4	0.20	0.047	59.5	3.7	6.22	0.50±0.18
	5	0.20	0.063	59.5	4.0	6.84	0.54±0.19
	6	0.20	0.242	59.3	3.9	6.58	0.50±0.16
	7	0.10	0.074	60.3	3.8	6.30	0.37±0.14
	8	0.10	0.113	60.9	4.0	6.56	0.55±0.20
Sexual maturity SM, days Dojrzałość płciowa DP, dni	1	0.00	–0.151	152.2	9.0	5.91	0.44±0.10
	2	0.00	–0.427	156.3	10.4	6.65	0.31±0.10
	3	0.00	–0.268	167.8	9.6	5.72	0.35±0.10
	4	0.00	–0.196	146.6	9.5	6.48	0.47±0.14
	5	0.00	–0.104	146.6	9.4	6.41	0.39±0.11
	6	0.00	–0.300	151.5	7.7	5.08	0.45±0.15
	7	0.00	–0.233	150.9	7.0	4.60	0.48±0.16
	8	0.00	–0.368	150.8	8.6	5.70	0.41±0.12
Egg production to 39 weeks – P, eggs Nieśność do 39 tyg. – N, szt.	1	0.70	0.523	98.1	13.6	13.86	0.27±0.08
	2	0.80	0.627	97.5	13.3	13.64	0.22±0.09
	3	0.80	0.492	87.2	12.1	13.88	0.36±0.10
	4	0.80	0.375	108.0	13.7	12.69	0.32±0.13
	5	0.80	0.261	104.5	14.7	14.07	0.28±0.13
	6	0.70	0.519	101.9	12.6	12.37	0.24±0.11
	7	0.90	0.475	103.6	13.4	12.93	0.26±0.12
	8	0.90	0.441	105.1	8.51	8.10	0.24±0.09

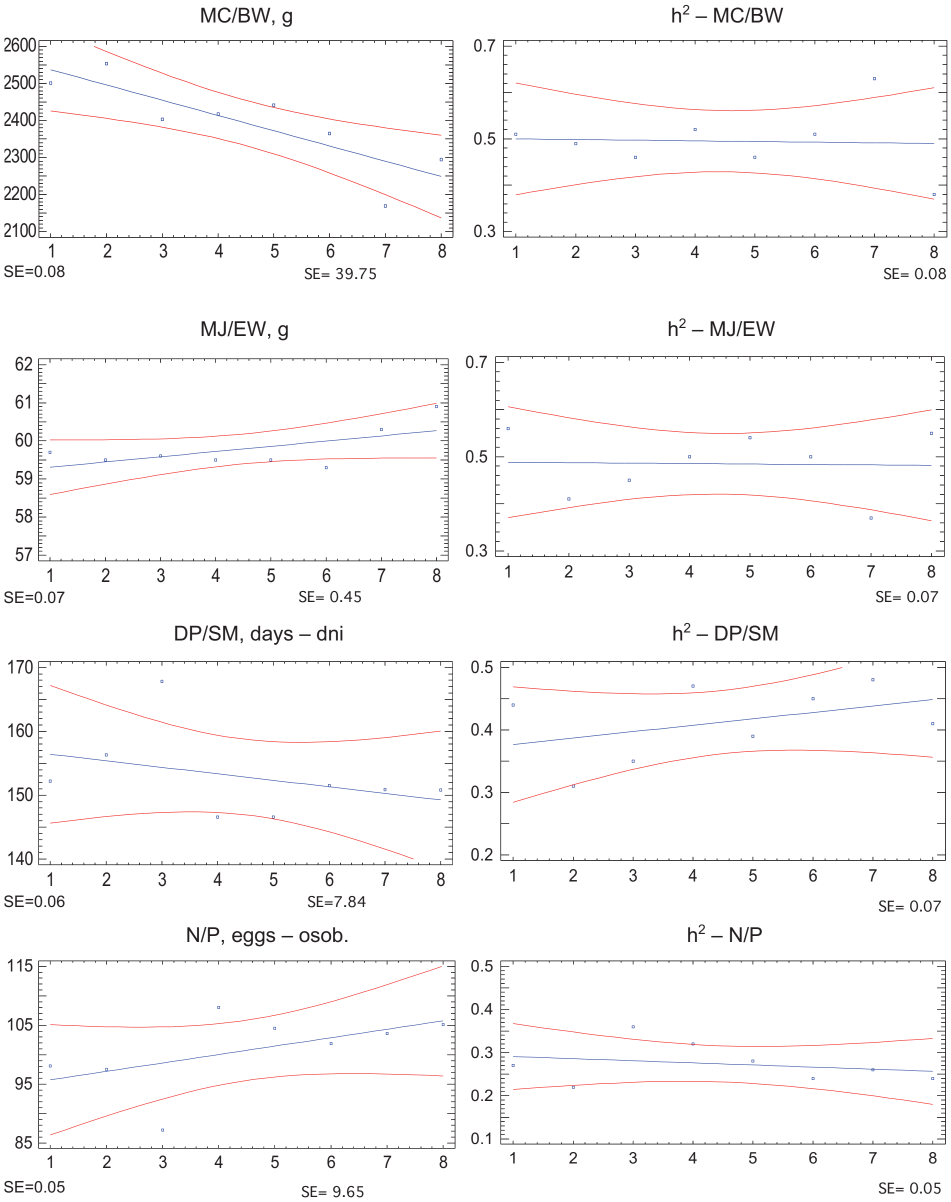

Fig. 1. Trends in productive traits and coefficients of heritability (h^2) in line N-11

Rys. 1. Trendy czasowe cech produkcyjnych i współczynnika odziedziczalności (h^2) w rodzie N-11

The coefficient of heritability for a given trait within a line changes not only between the lines but also between the generations. For this reason, estimation of heritability coefficients is still valid in the process of genetic improvement of populations. The literature and the present study show that unlike egg production ($h^2 = 0.2 – 0.3$), body weight ($h^2 = 0.4 – 0.6$) and egg weight ($h^2 = 0.4 – 0.5$) are highly heritable traits, which makes these traits easy to improve [Flock 2002]. The coefficients of heritability (h^2) estimated in the analysed lines are consistent with those reported in the literature [Szwaczkowski 1995, Settar and Turkmunt 1998, Anang et al. 2000, Hartmann et al. 2003]. The decrease in h^2 values confirms the well-known fact that selection reduces genetic variation and thus decreases the coefficients of heritability. Meanwhile, Nordskog et al. [1991] attributed the lack of time trends for the changing heritability coefficients of traits to the effect of unlimited additive genetic variation in the population in which a certain selection method had been used.

It is concluded that as a result of implementing the genetic improvement programme for the New Hamshire population based on NOVASEL electronic data processing system, satisfactory breeding and production results were achieved. Over the 8 generations, the number of eggs laid increased and body weight decreased while the mean egg weight was maintained at about 59–60 g. Research shows that positive trends in production traits result from moderate rather than maximized selection intensity, and that this is also the result of the population improvement strategy used. The use of a proper selection system which ensured that the mated cockerels and hens were two generations apart, contributed to the low inbreeding ($F_x < 1\%$) of individual populations. This is why the degree of homozygosity had no significant effect on the productivity and the estimated genetic parameters.

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TRENDY CECH PRODUKCYJNYCH I GENETYCZNYCH W RODZIE KUR NIEŚNYCH NEW HAMPSHIRE W CIĄGU 8 POKOLEŃ

Streszczenie. Celem badań było określenie kształtowania się parametrów genetycznych i produkcyjnych kur nieśnych New Hampshire ród N-11 w ciągu 8 pokoleń. Indywidualną kontrolą użytkowości objęto: masę ciała w 33. tyg. życia kur (g), masę jaja w 30. tyg. życia kur (g), wiek osiągnięcia dojrzałości płciowej wyrażoną liczbą dni życia w momencie zniesienia pierwszego jaja (dni), liczbę jaj zniesionych do 39. tyg. życia kur (osob.). W wyniku realizacji programu genetycznego doskonalenia w oparciu na systemie elektronicznego przetwarzania danych *NOVA-SEL* w rodzie N-11 zwiększono nieśność i przyspieszono wiek zniesienia pierwszego jaja, przy obniżeniu masy ciała kury. Analiza oszacowanych wartości efektywnej wielkości populacji (N_e) i współczynnika inbredu (F_x) wskazuje, że zastosowany w reprodukcji stad system kojarzeń kogutów i kur skutecznie chroni populację przed wzrostem zinbredowania.

Słowa kluczowe: dojrzałość płciowa, kury nieśne, masa ciała, masa jaja, nieśność

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