Estimates of genetic parameters and genetic gain for reproductive traits in the herd of Polish Landrace sows for the period of 25 years of the breeding work

Abstract
Evaluation of the 25-year breeding work on PL sows (4816) over 1973-1999 and the line PL-23 (925) in 1984-1999 maintained in the closed pig herd in Pukarzów. Data sets were analyzed by using restricted maximum-likelihood programs. The estimated heritability factors of breeding usability characteristics remained at a low level and were, in the case of the population of the PL race sows: $h^2 = 0.023$ for the number of live piglet births (NBA), $h^2 = 0.027$ for the number of piglets on the 21st day (NW21), $h^2 = 0.030$ for the litter weight (LW21). The heritability of analogous indicators for line PL-23 sows was: 0.061, 0.058 and 0.075 respectively. Average genetic gain for PL were -.05 pigs/yr, -.04 pigs/yr, -.48 kg/yr for NBA, NW21 and LW21 respectively. Genetic trends for reproductive performance PL-23 breed were .17 pigs/yr, .10 pigs/yr, .54 kg/yr for NBA, NW21 and LW21 respectively.

Key Words: genetic gain, genetic parameters, reproductive traits, pig

In the late 1960s in Poland, in spite of the use of a strict selection, a lack of the genetic gain in the scope of breeding usefulness was ascertained. Besides that, in fattening and carcass characteristics, a regression was observed. For that reason, to allow the further improvement of the stock, with the beginning of the 1970s, work over the new organization of pig farming in Poland began, intended on consolidation of pure-breeds [DUNIEC and RÓŻYCKI, 1972; RÓŻYCKI, 1974, 1977]. Having these premises in mind, breeding centres were appointed in 1974 (closed herds) to produce specialized lines, intended in the future for interbreed crossing and interlinear crossing, and to prevent disease conveyance. The essential target, which inspired the idea to create large breeding units, was the differentiation of the population of pigs within national breeds and the limitation of the inflow of pigs’ genes resulting from importation.
Bearing in mind the minimization of inbreeding, it was assumed that at least 8 groups of sows and 8 groups of boars should enter the breeding centre [RÓZYCKI, 1977]. Breeding and selective work were held on the basis of a previously established breeding program. The next emphasized problem in the breeding and selective work at breeding centres was the useful characteristics’ improvement, important from the economic point of view. In this aspect, special attention was paid to the improvement of the growth rate and better utilization of the fodder, the improvement of meat characteristics and reproductive usefulness. The program of genetic improvement of useful characteristics of the national pig herd was realized in Poland in 32 economic(breeding) centres, attaining different stages of program realization and diverse level of productivity coefficients [BUCZYŃSKI, 1988; SŁOMKOWSKI, 1985]. The basic imperfection was the lack of exact verification of established breeding targets, with reached performance. Although to work out the breeding programs was of great importance, most often there was not sufficient time or patience to check into which measure these plans became realized. The minute recognition of effectiveness of the breeding work held in Poland in the scope of pigs [SŁOMKOWSKI, 1985; BUCZYŃSKI, 1988; KAPLON, 1991; LECHOWSKA, 1998] determined the encouragement to enter upon research concerning this problem.

In this work an attempt has been made to present an assessment of the results of breeding work with a herd of breeding pigs in Pukarzow. Genetic parameters and genetic trends have been assessed, since knowing the values of these parameters for characteristics which should be improved when breeding in a specific population using sound assessments is indispensable for the efficient development of a breeding programme for future years.

Materials and methods
The material for the study consisted of data relating to 16,528 litters including 4,816 first litters (PL) and 2,417 litters which included 925 first litters (the PL-23 line), recorded in zootechnical documentation held at the Pig Breeding Farm in Pukarzow for the period 1973 to 1998. This performed work includes results concerning the PL breed in fourteen generations concerning a time period of 26 calendar years, and lines PL-23 in ten generations for the cycle of 15 years.

Heritability and repeatability indicators were calculated for the following characteristics: fertility (the number of live piglet births - NBA), the number of piglets raised (NW21), litter weight (LW21).

Genetic correlations were defined between the following characteristics:
1. fertility and the number of piglets on the 21st day,
2. fertility and the litter weight on the 21st day,
3. the number of piglets raised and the litter weight on the 21st day.

The heritability and repeatability of the characteristics and genetic correlation was assessed applying Eildert Groeneveld’s VCE 4.2.5 computer program using the REML (Restricted Maximum Likelihood Procedure) method. In estimating the parameters, an individual model was used because an animal model takes into account all genetic and environmental links so the calculations are not affected by selection errors, and hence they appear to give the most credible value estimates for breeding animals [ADAMEC and JOHNSON, 1997; GROENEVELD et al., 1992; CHEN et al., 2003;
Breeding usability indicators for PL breed sows were calculated using the model:

\[ Y_{ijklmno} = \mu + R_i + S_{ij} + RM_{ijk} + M_{ijkl} + p_m + a_n + c_m + e_{ijklmno} \]

- \( Y_{ijklmno} \): the phenotype value of the individual
- \( \mu \): population mean
- \( R_i \): the fixed influence of the sow’s birth year
- \( S_{ij} \): the fixed influence of the litter birth season
- \( RM_{ijk} \): the fixed influence of the litter birth year
- \( M_{ijkl} \): the fixed influence of the subsequent litter
- \( p_m \): the random influence of the maternal environment
- \( a_n \): the random additive genetic value of the individual
- \( c_m \): the random genetic influence of the mother
- \( e_{ijklmno} \): the random influence of the environment.

In the case of the sows of the PL-23 line the calculations were carried out using the following model:

\[ Y_{ijklmno} = \mu + R_i + S_{ij} + RM_{ijk} + M_{ijkl} + p_m + e_{ijklmno} \]

The basis for determining genetic trends in population studies were solutions for the year of birth of the individual describing changes in genetic quality over time. Genetic progress was expressed as a straight-line regression coefficient. The calculations were carried out using Ignacy Misztala’s BLUPf90 computer program utilising a multi-characteristic individual model, taking into account the same fixed and random factors as in the case of the genetic parameters.

### Results

The estimated heritability factors of breeding usability characteristics remained at a low level and were, in the case of the population of the pbz race sows: \( h^2 = 0.023 \) for the number of live piglet births (NBA), \( h^2 = 0.027 \) for the number of piglets on the 21\textsuperscript{st} day (NW21), \( h^2 = 0.030 \) for the litter mass (LW21) (Tab. 1). The heritability of analogous indicators for line pbz-23 sows was: 0.061, 0.058 and 0.075 respectively (Tab. 2). The estimated parameters for characteristics linked to reproduction showed an admittedly small, but significant influence of genetic principles on the fertility characteristics of the females.

<table>
<thead>
<tr>
<th>h(^2)</th>
<th>NBA</th>
<th>NW21</th>
<th>LW21</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBA</td>
<td>0.023</td>
<td>r(_G) - (0.985)</td>
<td>r(_G) - (0.781)</td>
</tr>
<tr>
<td>NW21</td>
<td>r(_G) - (0.985)</td>
<td>0.027</td>
<td>r(_G) - (0.823)</td>
</tr>
<tr>
<td>LW21</td>
<td>r(_G) - (0.781)</td>
<td>r(_G) - (0.823)</td>
<td>0.030</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>h(^2)</th>
<th>NBA</th>
<th>NW21</th>
<th>LW21</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBA</td>
<td>0.061</td>
<td>r(_G) - (0.984)</td>
<td>r(_G) - (0.891)</td>
</tr>
<tr>
<td>NW21</td>
<td>r(_G) - (0.984)</td>
<td>0.058</td>
<td>r(_G) - (0.901)</td>
</tr>
<tr>
<td>LW21</td>
<td>r(_G) - (0.891)</td>
<td>r(_G) - (0.901)</td>
<td>0.075</td>
</tr>
</tbody>
</table>
The values of the genetic correlation coefficients between the breeding usability characteristics of the PL race sows analysed are presented in Table 1. From the data therein it can be concluded that the high dependencies between the characteristics means that it is permissible to take just one of them into account when selecting, e.g. the number of piglets reared to the 21st day of life.

The number of farrows born alive was significantly correlated \( (r_G = 0.985) \) with the number of farrows at day 21 of life \( (r_G = 0.781) \) and with the litter weight at day 21. The correlation between the number of farrows at day 21 of life and with the litter weight in this period achieved the level of \( r_G = 0.823 \). Genetic correlation coefficients were also high for the PL-23 breed (Tab. 2). As ascertained in the author’s own research, there is a high positive correlation between the sow breeding useful characteristics.

The next very important parameter in breeding and selective work is the repeatability of production characteristics (i.e. the ability to repeat the same values in subsequent litters). The results given in Table 3 show that the estimated repeatability of the useful breeding characteristics ranged from 0.116 to 0.236.

<table>
<thead>
<tr>
<th>Item</th>
<th>PL breed</th>
<th>Line PL-23</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBA</td>
<td>0.117</td>
<td>0.209</td>
</tr>
<tr>
<td>NW21</td>
<td>0.116</td>
<td>0.193</td>
</tr>
<tr>
<td>LW21</td>
<td>0.122</td>
<td>0.236</td>
</tr>
</tbody>
</table>

Table 3
Repeatability coefficients of the breeding usage characteristics \( r^2 \)

<table>
<thead>
<tr>
<th>Breeding characteristics</th>
<th>Straight-line regression coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL</td>
<td>NBA (-0.005)</td>
</tr>
<tr>
<td></td>
<td>NW21 (-0.044)</td>
</tr>
<tr>
<td></td>
<td>LW21 (-0.484)</td>
</tr>
<tr>
<td>Line PL-23</td>
<td>NBA (0.166)</td>
</tr>
<tr>
<td></td>
<td>NW21 (0.099)</td>
</tr>
<tr>
<td></td>
<td>LW21 (0.544)</td>
</tr>
</tbody>
</table>

It was shown that estimated genetic trends for sows of the PL breed (Tab. 4, Fig. 1, 2) had been very minor and not always desirable. Negative directions of changes in number of born alive and reared farrows (Fig. 1) appeared in 1975-1983 and 1985-1992. Analysing the formation of the genetic trend for litter weight (Fig. 2), the rise of estimated breeding values in sows by 1983 was ascertained, whereas from 1985 the values were decreasing, and the renewed positive trend appeared from the year 1992. The results of the tendency valuation expressed with the standard deviation for the line PL-23 were shown in Fig. 3 and 4. The graphic image of the trend value evidences the positive direction of changes, both for the number of born and reared farrows, and for the litter weight.
Fig. 1: Genetic trends in PL
Genetische Trends (Rasse PL)

Fig. 2: Genetic trends for LW21 (PL)
Genetische Trends der Wurfmasse (PL)

Fig. 3: Genetic trends (PL-23)
Genetische Trends der Linie PL-23
Discussion

The planned target will not be achieved by the selection based on the animal phenotype, and often undesirable results may be achieved. Separation of genetic variability in the population, and by that a heritability coefficient, is extremely important, as this parameter determines the effectiveness of the selection and the level of predicted genetic gain, with respect to the certain period of time and at the specific selective difference. The numerical values of breeding characteristics’ heritability obtained in this work correspond with the results for the wbp breed reported by BIZELIS et al. [2000], KAPŁON et al. [1990a], HANENBERG et al. [2001] (for sows Dutch Landrace) and HAMMANN et al. [2004] (0.09 – 0.15 for the number of farrows born alive for the breed Pietrain and Teutons Landrace, respectively). Convergent results regarding the number of farrows born alive ($h^2 = 0.12$) and the litter weight ($h^2 = 0.09$) were obtained by ADAMEC and JOHNSON [1997] who investigated the sows of the breed Large White and Landrace from pedigree herds in Czech Republic. However, BUCZYŃSKI [1988] obtained the following heritability coefficients: $h^2 = 0.152$ (for the number of farrows of day 1.), $h^2 = 0.096$ (for the number of farrows at day 21.) and $h^2 = 0.154$ (for litter weight). Higher coefficients of this parameter were obtained by LEWCZUK et al. [1991c]. According to them, the average heritability for the total number of farrows born alive, in the whole of the sow’s productive life for the PL and PLW breeds, amounted to respectively 0.256 and 0.267, and farrow at day 21 numbered 0.238 and 0.255, and litter weight 0.403 and 0.410. Similar results are reported by LECHOWSKA [1998]. Low heritability coefficients indicate not only the susceptibility of the breeding characteristics on the activity of environmental factors (which actively control the efficiency of a sow organism), but also on the great constancy of the genetic information being descended from the parents. The reported values show that the genetic lability has a small share in the entire phenotypic liability, observed between sows. Thus, it can be inferred from the obtained $h^2$ values that phenotype-based selection not greatly increases the chance of the breeding characteristics’ improvement. The selection based on the results of breeding value estimation should be done in the sow herd of the PL breed, by use of the most currently reliable BLUP method. In Denmark, for example, a combined procedure is
applied to estimate the breeding value in respect of the breeding use, emphasizing the $h^2$ and repeatability of the feature, using the selection focused on the optimum litter size [SORENSEN, 1991].

The analysis of breeding characteristics in the author’s own research showed a high level of genetic connectedness, which evidences the possibility to limit the selective criteria to one feature only. Similar results concerning correlation between the characteristics useful for breeding in sows were achieved by KAPŁON et al. [1990a] for sows of the PLW breed (0.91 NBA-NW21, 0.68 NBA-LW21, 0.81 NW21-LW21). Slightly lower coefficients of the above parameter were received by LEWCZUK et al. [1992]. These authors showed the following correlations in sows of the pbz breed, investigated in the years 1970-1985: between the number of farrows born alive and the number of farrows at day 21 $r_G = 0.770$, between the number of farrows born alive and litter weight $r_G = 0.671$ and between the number of farrows born alive at day 21 and litter weight $r_G = 0.797$.

For sow breeding success the knowledge of the characteristics’ repeatability in the following litters is crucial. The above parameter for breeding characteristics accepted values from 0.12 to 0.24. A slightly different value for the analysed feature in sows of pbz breed was achieved by LEWCZUK et al. [1991c] ($r_P = 0.169$ LU, $r_P = 0.169$ LO, $r_P = 0.183$ M21). Repeatability coefficients for the PLW breed [LEWCZUK et al., 1991c] totalled respectively: 0.157 NBA, $r_P = 0.136$ NW21, $r_P = 0.175$ LW21. Then, according to KUJAWIAK and RATAJSZCZAK [1992] it fell into the following ranges: for NBA $r_P = 0.196-0.195$, NW21 $r_P = 0.162-0.165$ and LW21 $r_P = 0.226-0.199$. However, according to BUCZYŃSKI [1988], the repeatability of the farrow number at birth amounted to $r_P = 0.148$, numbers of reared farrows at day 21 $r_P = 0.193$ and the litter weight $r_P = 0.242$. LECHOWSKA [1998] and ORZECHOWSKA [1998] asserted that the value of this parameter for breeding use reaches the level of 0.14 – 0.23. As a result of the low values of repeatability coefficients of the described characteristics, the accuracy of the estimation of the reproductive ability in sows increases along with the quantity of the following litters taken into account. For that reason, a late estimation of the multiparous sows increases the accuracy. However, it is responsible for the extension of the distance between generations, which simultaneously bears on the decrease of the genetic gain.

The primary target of the breeding work is the improvement of the genetic value of the pedigree herd. Changes in productiveness, appearing over long time periods, and caused by the differences of the average value of the genetic population, are qualified as genetic trends [ATIL, 2000; KUNAKA et al., 2001]. Understanding the value of genetic changes gives much of the most valuable information concerning, first of all, estimation of the efficiency of practical breeding methods. The genetic trends for each feature analysed in this work for the population of sows were estimated on the grounds of solutions for the following years of birth, received at the simultaneous estimation of constant and accidental influence, on the grounds of individual model equations, i.e. a BLUP method. It has to be stated that the genetic reactions for characteristics useful in breeding in the analysed population of sows were small and not always desirable. Genetic progress related to the PL breed for NBA amounted to on average $-0.005$, for NW21 $-0.04$ and for LW21 $-0.48$ (Tab. 3). The lack of efficiency in selection made for breeding characteristics, estimating sows of the PL breed from southeastern Poland, was also reported by LECHOWSKA [1998]. However, in the author’s own research,
the regression of the number of farrows born alive, reared farrows and the litter weight in sows of the PL-23 line was proved as positive. Estimated values of the genetic progress of the above characteristics totalled respectively: . 17 (NBA), . 10 (NW21) and . 54 (LW21). The results concerning genetic trends shown in the presented work are difficult to compare because of the scarcity of reports in the national literature concerning these issues. The trends estimated on the grounds of the genetic animal value with the utilization of the REML method by KAPŁON et al. [1990b], for the PLW breed were as follows: . 01 ± . 01 for the number of farrows born alive and farrows at day 21, and . 45 ± . 06 for litter weight. In France, as a result of the breeding work from 1977-1998, positive changes in the genetic value for the survival rate of embryos and numbers of farrows born alive were reported [TRIBOUT et al., 2002]. As SOUTHWOOD and KENNEDY [1991] reported for the Yorkshire and Landrace breeds included in the breeding program from 1977-1987, the genetic trends were very small and negative, as indicated by results from -.012+/-.004 to .004+/-0.002 for farrows per year. Very small, though positive trends, were achieved in Brazil [FILHO et al., 2005]. In the United States CHEN et al. [2003] estimated the efficiency of breeding work in the herd of sows from the National Register of Pigs. The authors stated that genetic changes were positive and amounted to . 018 farrows/year and . 114 kgs for the weight of farrows at day 21/year.

The obtained positive values of genetic trends prove the correctness of direction in the breeding work and proper selection of animals for mating. However, their low values prove a low selection efficiency, which probably results from including a large number of characteristics into the breeding program, and the use of selective criteria relying only on the animals’ own phenotype. As a consequence, it can be predicted that the continuation of the work in herd with the utilization of presently available methods of genetic analysis - BLUP animal model, will permit a more precise estimation of productivity coefficients, and simultaneously the use of these values to direct the selection.

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