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Decrease in pig fertility as a result of reciprocal translocations and associated economic effects on the basis of rcp(7;13)(q13;q46)

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Abstract. Reciprocal translocations, very frequently identified in pigs, are the cause of fertitlity decrease. The aim of this work was to provide an objective assessment of the real effect of reciprocal translocation (7;13) on the fertility of carriers and associated economic effects. The experiment has shown that fertility, expressed as a mean litter size, decreased by 48% in comparison to that of the control group. On the basis of simulation account, financial losses incurred a translocation - as a result of using carrying boar in a commercial herd were estimated at about 8,000 USD for natural mating and at about 162,000 USD for artificial insemination. The results obtained show the need for introducing a system for cytogenetic control of boars producing small litters into the Polish swine improvement programme .

Key words: karyotype, litter size, pigs, reciprocal translocation, simulation account.

Introduction

Reciprocal translocations, involving exchange of chromosome fragments of two different pairs, are structural aberrations exceptionally common in pigs. More than 60 translocations of this type have been diagnosed so far in pigs. They involve chromosomes of all pairs, but their incidence is not particularly characteristic of any of the breeds (GUSTAVSSON 1990, SYSA 1991). The majority of these aberrations originate "de novo" as a result of chromosome breaks. This suggests a high sensitivity of the domestic pig genome to environmental

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effects. Expression of this aberration is shown by a decreased fertility (expressed by litter size) caused by a post-zygotic selection of aneuploid embryos. On the other hand, boars affected by a translocation in balanced form are developing normally and contribute to a rapid spread of these defects among populations. Carriers of reciprocal translocations have normal external appearance, and males have normal semen parameters. Data presented in the literature show that reciprocal translocations decrease fertility by 5 to 100%, but their effects depend on the morphology of the chromosomes involved, on the location of breakage points, and on the size of translocated chromatid fragments (GUSTAVSSON 1990, LONG 1991).

Three different reciprocal translocations have been identified so far in Poland: rcp(1;5)(q21;q21), rcp(8;14)(p21;q25), rcp(7;13)(q13;q46) (DANIELAK-CZECH et al. 1994). The effect of translocation rcp(1;5) on fertility was not determined because its carrier was elimitated from breeding, while translocations rcp(8;14) and rcp(7;13) caused litter size to decrease by 25% and 11%, respectively. However, these effects are not objective as they were calculated for single carriers based on the data from several litters. A more considerable decrease in fertility was expected in the case of translocation rcp(7;13) due to the course of gametogenesis. During this process, in addition to incorrect quadrivalent segregation, also unbalanced gametes may have been created as a result of crossing-over in the area between the centromere and the breakage/rejoining point. This should be reflected in a greater fertility decrease than was first ascertained, which could be detected on the basis of a large number of litters obtained from a more numerous group of carriers of this translocation.

The aim of this work was to make an objective assessment of the real effect of reciprocal translocation (7;13) on pig fertility and associated economic effects.

Material and methods

In order to select animals for the experiment it was necessary to carry out a cytogenetic study of 150 piglets, the offspring of the translocation carriers (Figs. 1, 2) as well as of animals free from chromosomal aberrations (the parents' karyotype was determined earlier within the cytogenetic evaluation of the herd). Karyotype was analysed using conventional Giemsa staining, RBA (DUTRILLAUX et al. 1973) and GTG (WANG, FEDOROFF 1972) techniques. These analyses of genotype distribution made it possible to select 28 sows and 8 boars from the animals under examination (with regard to require-

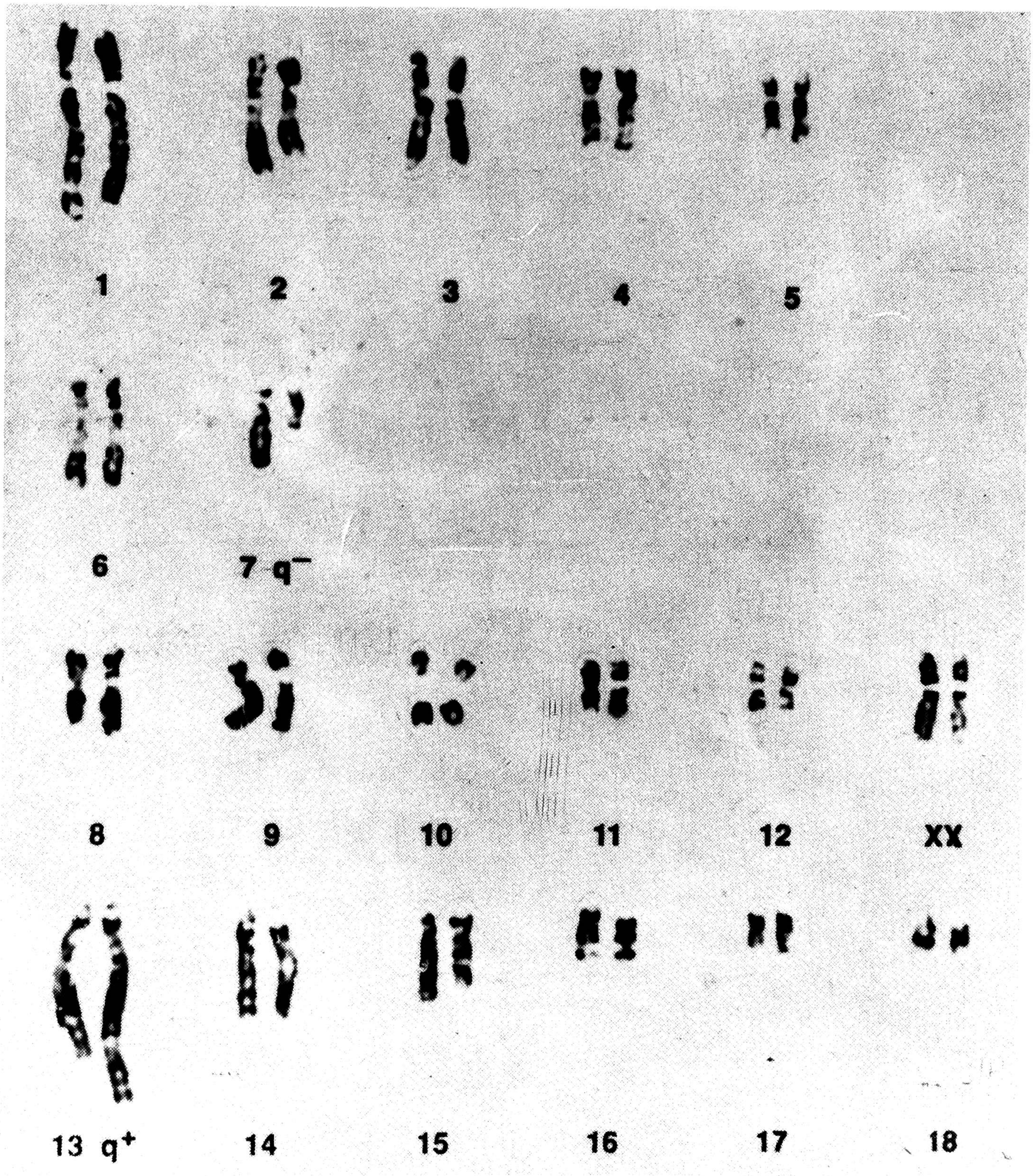

Fig. 1. Karyotype of a sow, carrier of reciprocal translocation (7;13)(q13;q46) – GTG technique

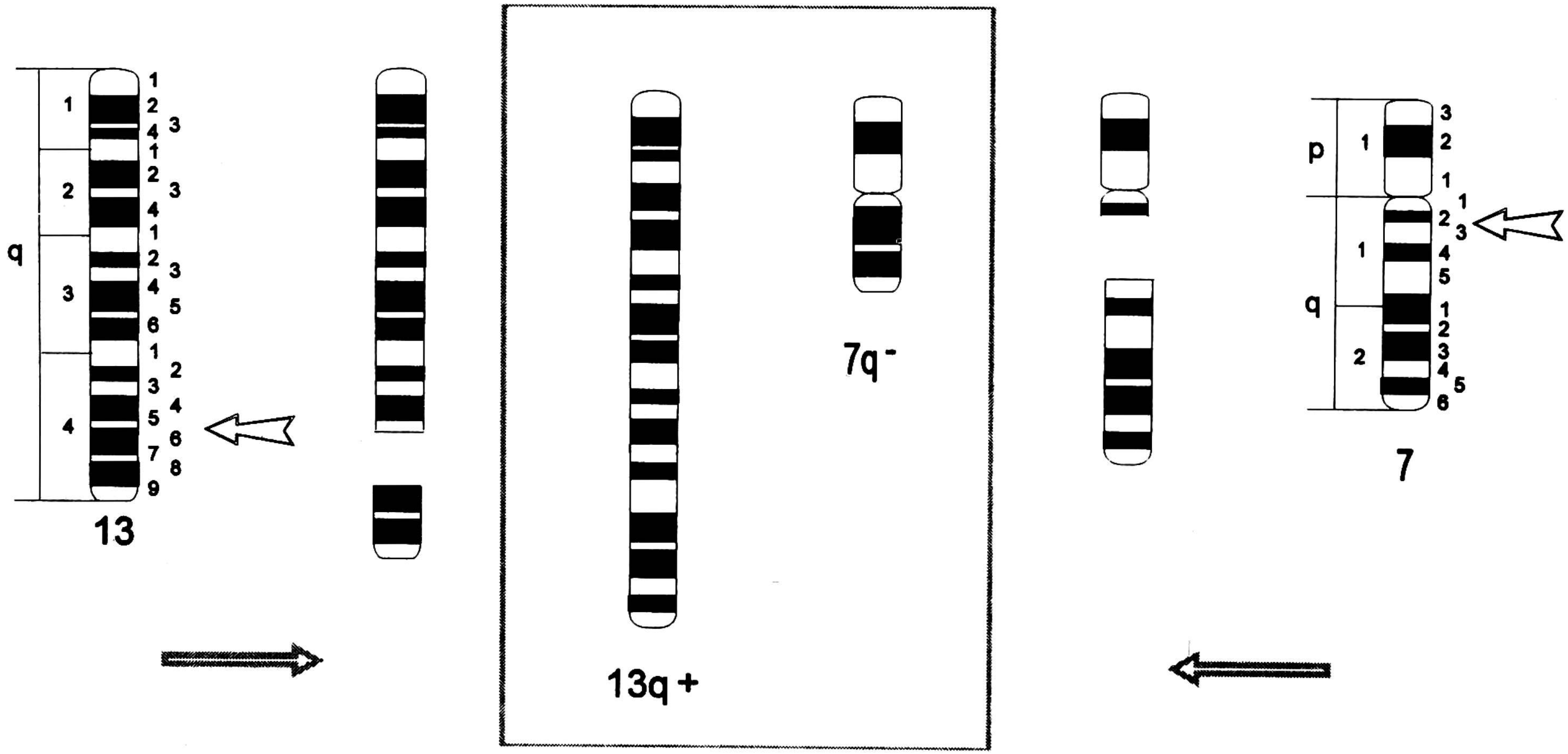

Fig. 2. A scheme of reciprocal translocation (7;13)(q13;q46) with chromatid breakage/rejoining points indicated

ments for sex, karyotype and degree of relationship). These animals were later used in mating according to the project of the experiment, whereby four parental groups were used: two groups of carriers of reciprocal translocation (7;13) and two control groups.

According to the experiment (using the number of live and still-born piglets in litter as an exponent of fertility) the size of the first two litters was registered for each parental pair. These data were a basis for calculating the mean litter size in the first and second litter for particular genotype groups. Next, the experimental groups were compared statistically by the analysis of variance and Duncan multiple range test.

To determine the economic and productive efficiency of eliminating translocation-carrying boars from breeding, a hypothetical financial effect was analysed as a result of an individual present in the commercial herd and used in natural mating or in artificial insemination. The simulation account involved using farrowing percentage of the sows from the herd under examination followed by comparing differences between farrowing percentages of control sows and sows from the group of translocation carriers. The simulation account assumed using the translocation-carrying boar in artificial insemination and calculated losses of profit resulting from reduced prolificacy of sows inseminated with its semen, losses of gross commercial value from the sales of fatteners, and losses resulting from the death of one-day-old piglets (assuming the actual costs of piglets from in the research period).

Results

Mean litter size was calculated for particular genotype groups on the basis of data on litter size (live and still-born piglets in two litters).

The calculated means served as a basis for a statistical analysis using the analysis of variance. To increase the number of experimental factors each litter was treated as one sample. The analysis of variance showed highly significant differences between the groups under investigation. The multiple range test carried out to indicate differences between the groups showed that both the group of translocation-carrying sows and that of translocation-carrying boars differed highly significantly from two control groups. However, this test showed no differences between the group of translocation-carrying boars and the group of translocation-carrying sows. No statistically significant differences were found between the control groups.

Table 1. Mating programme and results obtained for experimental groups of pigs

Experimental group	Mating type ♂ × ♀	Mating number	Number of piglets in litters (still-born included)		Mean litter size (live and still-born)
			first	second	
A – rcp carriers	$rcp^{+} \times rcp^{-}$	7	34 (7)	37 (5)	5.07
B – rcp carriers	$rcp^{-} \times rcp^{+}$	7	25 (6)	33 (7)	4.14
Mean					4.61
C – control group	$rcp^{-} \times rcp^{-}$	7	57 (5)	64 (3)	8.64
D – control group	$rcp^{-} \times rcp^{-}$	7	62 (5)	65 (14)	9.07
Mean					8.86

rcp^{+} – a carrier of reciprocal translocation in a heterozygous form, rcp^{-} – an individual with normal karyotype.

Table 2. Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	55	426.98	
Between-group	3	260.19	86.73
Within-group	52	166.79	3.21

$F_{calc.} = 27.02$, $F_{0.05} = 2.79$, $F_{0.01} = 4.18$.

Table 3. Comparison by Duncan test of differences between mean litter size calculated for experimental groups of pigs

Experimental group	Mean litter size	Groups compared	Differences between means	$D_{0.01}$
D	9.07	D – C	0.43	3.25
C	8.64	C – A	3.57	3.25
A	5.07	A – B	0.93	3.25
B	4.14	D – A	4.00	3.39
		C – B	4.50	3.39
		D – B	4.93	3.48

Fertility of the translocation carriers in comparison with the control group animals, calculated on the basis of mean litter size (Table 1) was found to decrease by 48%. Another characteristic of the herd were 4.2% piglet losses, calculated by comparing the number of piglets born and those reared until 21 days of age.

Table 4. Differences in prolificacy in the pig herd under investigation

Specification	Control group	Translocation carriers
Mean litter size	8.86	4.61
Prolificacy, %	100.00	52.00
Difference, %		48.00

The results of estimating the economic effect resulting from reciprocal translocations are shown in Tables 4-6.

The estimated financial losses caused by using one translocation-carrying boar in artificial insemination are comparable to:

– the loss of profit on a fattener farm with a yearly scale of production of 3,380 head,

– the loss of gross commercial value from the sale of 1,560 fatteners,

– the loss caused by the death of 11,267 one-day-old piglets.

Table 5. Hypothetical financial losses as a result of using a translocation-carrying boar in the commercial herd with natural mating

Specification	Production losses by one boar
Average sow prolificacy in specialized breeding in Poland: 19 piglets	48.00%
Annual losses per one sow:	
piglets (head)	9.12
piglets (zl*)	328.32
Losses caused by one boar servicing 60 sows per year:	
piglets (head)	547.00
piglets (zl*)	19,692.00

* prices as of 18 October 1995 (36.00 zl per one piglet, 1 USD ≈ 2.50 PLN)

Table 6. Estimated financial losses caused by using one translocation-carrying boar to inseminate Polish Landrace sows in an active population[a)]

Specification	Technical and economic indicators	No. of units
Rate of decreased prolificacy of sows	%	48.00
Average prolificacy of sows from an active population[b)]	head	21.86
No. of semen doses from one boar	head	1,650.00
Conception rate of sows[c)]	head	1,073.00
No. of piglets born in the herd free of translocation	head	23,456.00
their financial value	PLN	844,416.00
No. of piglets born from matings of a translocation carrying boar[d)]	head	12,189.00
their financial value	PLN[e)]	438,804.00
Financial loss due to using a translocation carrier	PLN[e)]	405,612.00

[a)] involved in evaluation and breeding
[b)] prolificacy on the first day after farrowing
[c)] with average conception rate of 65%
[d)] average prolificacy of sows mated to a boar carrying translocation: 11.36
[e)] 1 USD ≈ 2.50 PLN

Discussion

In many countries, reciprocal translocations are considered a major breeding problem because of their sharp decreasing effect on pig fertility. The greatest number of reciprocal translocations has been identified in Sweden as a result of intensive cytogenetic studies over the last 30 years. This was possible due to the karyotype control of animals selected on the basis of breeding records which indicated low litter size (5-7 piglets in comparison with the mean for the herd – 11 piglets). This made it possible to estimate to 50% the hypothetical frequency of translocation carriers in the Swedish population of boars whose fertility was reduced as reported by GUSTAVSSON at the First Symposium on Cytology of Farm Animals (Balice, 1984).

Many cases of translocations were also described in France, where pig karyotype studies were included in the national selection system of breeds, lines and particular animals for high fertility (LEGAULT 1985). As part of the programme whose criterion is litter size, 800,000 litters of 20,000 boars have been evaluated annually since 1970 and sires producing less than 8 piglets in

6 successive litters have been analysed cytogenetically (DAGORN 1978, POPESCU et al. 1984). In this way, the next cases of reciprocal translocations are diagnosed in a systematically created stock of boars with reduced fertility. On the basis of the results obtained, POPESCU and BOSCHER (1986) calculated that in France 42% of boars with reduced fertility were reciprocal translocation carriers. Assuming that the incidence of boars with lower fertility in a group of sires was 0.15% the authors estimated the frequency of reciprocal translocation carriers in the breeding boars population to be 0.06%.

In the United States the preliminary results showed that the proportion of boars with reduced fertility was 3.7%, which is 25 times higher than in France (ZHANG et al. 1991). This suggests a possible high incidence of translocation carriers. In this connection, the national system of boar selection PIG CHAMP has been in use in the breeding programme since 1990. It is based on principles similar to those in France.

Cytogenetic studies of pigs started recently in Finland gave surprising effects (detection of several translocations). Also in this case, the criterion for karyotype evaluation was the low litter size (MAKINEN et al. 1987, KUOKKANEN, MAKINEN 1988).

Single translocations were identified in pig populations bred in countries where no systematic control of pig karyotype is done. In view of that selection of animals for cytogenetic studies is most often random, or is based on breeding guidelines on animals suspected to have developmental abnormalities.

In Poland, pig karyotype control aiming to eliminate carriers of genetic defects is not imposed by breeding rules. Such analysis, possible but not obligatory, is included in the boar fertility evaluation programme, accomplished since 1990 (ROSŁANOWSKI 1989). So far a mere several hundreds pigs, mostly breeding and A.I. boars, randomly selected from the population, were involved in the cytogenetic studies (information about boar fertility, as a basis in karyotype evaluation, was not used) (DANIELAK et al. 1989, SYSA 1991, ŚWITOŃSKI, PIETRZAK 1992, DANIELAK-CZECH et al. 1994). The use of banding techniques in cytogenetic analysis made it possible to detect carriers of three different translocations from one small herd. This suggests that a significant proportion of the Polish pig population may be affected by karyotype rearrangements. Furthermore, because of a hereditary nature of translocations, the risk of transmitting the defect to a large number of animals and the risk of its establishment in the population is clearly increasing with intensive use of translocation carriers for reproduction.

Due to the influence of different individual factors affecting boar fertility an objective evaluation of the translocation effects was possible only after averaging results, obtained for a larger number of carriers and compared to those for a group of animals without aberrations.

An example is reciprocal translocation (7;13) used in this experiment, for which the decrease in fertility in relation to the mean for the herd was preliminarily calculated to be 11%, but after comparing data on many carriers and litters to the fertility of the control groups, the decrease was 48%. Characteristics of the population on the basis of the concrete numerical data, used in the simulation model, made it possible to determine economic losses connected with one translocation-carrying boar used in the herd in natural mating (19,692 PLN = about 8,000 USD) and in artificial insemination in the active population (405,612 PLN = 162,000 USD).

A similar analysis of the economic effect of a reciprocal translocation, which caused fertility in carriers to decrease to 45%, was made in France using the simulation model PORSIM (TEFFENE, SALAUN 1983). The evaluation involved comparing inputs and returns of two equinumerous herds of sows (21 each), one being mated to a translocation-carrying boar, the other to a boar with a correct karyotype. Direct financial losses of the farm resulting from the failure to produce piglets (at the conception rate of 65%) were estimated at 6,000 USD (POPESCU et al. 1984). Losses caused by using a translocation-carrying boar at the A.I. station were estimated at 105,000 USD (with 650 semen doses from one boar) (BONNEAU et al. 1991).

Economic analyses of thousands of litters were also made in the former German Democratic Republic in connection with the detection of a reciprocal translocation which caused boar fertility to decrease slightly (by 5%). Direct losses incurred by a year-long utilization of the boar in reproduction were estimated at 28,650 DM, but the global costs resulting from the introduction of its offspring into the herd were much higher owing to the accumulation of a small individual effect in a large population (GOLISCH et al. 1984, GOLISCH 1989).

Another attempt at estimating financial losses incurred by small farms using carriers of two reciprocal translocations during a short period was made in Sweden. The losses ranged from 6,000 to 25,000 USD (GUSTAVSSON et al. 1982).

The results of analyses of reciprocal translocation effects made in the countries where the central systems of cytogenetic control are in force as well as similar results of analyses of economic effects obtained for translocation (7;13) in the experimental herd suggest that it is necessary to:

– eliminate animals (boars and sows) affected with the structural chromosomal rearrangements from the herd,
– introduce karyotype evaluation as an additional criterion of selection to be used in the national pig improvement system,
– include a group of breeding boars tending to produce smaller size litters (on the basis of mean litter size approved for the domestic population) in the national cytogenetic control system.

These suggestions comply with the Instruction of the Ministry of Agriculture, Forestry and Food Economy on the "Studies and evaluation of boar reproductive ability" and with the detailed guidelines included in the "Project for pig reproduction control in Poland with regard to cytogenetic methods", worked out by SYSA (1991). The author proposes concrete criteria whereby the following animals should be cytogenetically tested:
– boars producing less than 7 piglets in 10 successive litters,
– boars and sows whose reproductive effects are lower than of other sires used under comparable conditions,
– boars affected with oligospermia, azoospermia, and testicular hypoplasia, as well as intersexual individuals and those suspected to have genetically induced developmental abnormalities.

These practical guidelines can be restricted to the cytogenetic control of animals tested for fertility and already admitted to reproduction (those managed at Animal Breeding and Artificial Insemination Stations, in breeding centres, and on reproductive farms), and complying with the first of the criteria mentioned above. Restriction of the investigated group of animals to a reproductive sector efficiently prevents genetic defects from spreading in a population on the one hand, and maximally limits the number of animals which have to be put to the karyotype control, on the other. This is important when the time-consuming character of pig karyotype evaluation, based on precise banding techniques, makes it impossible to carry out a cytogenetic analysis of all boars and sows intended for reproduction. The introduction of the discussed project involves serious difficulties concerning the need of a systematic collection of data on boar breeding ability including litter size. On this account early selection of animals with decreased fertility from the national population of sires constitutes a problem. This situation may be changed by setting up a central database, which would make it possible to introduce the national system of pig cytogenetic control into the breeding evaluation programme.

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