Genetic gain, increase in inbreeding rate and generation interval in alternatives of Pinzgau breeding program

O. Kadlečík[1], R. Kasarda[1], L. Hetényi[2]

[1]Slovak Agricultural University, Nitra, Slovak Republic
[2]Research Institute of Animal Production, Nitra, Slovak Republic

ABSTRACT: The aim of this paper was to analyse alternatives of Pinzgau breeding program. Alternatives were optimised for genetic gain of selection index composed of parameters of milk efficiency traits and increase in inbreeding per generation. A scheme using the mating of 70% old proven sires led to a lower increase in inbreeding per generation from 0.248% to 1.903% than a young sires scheme with 0.313–2.177% or 0.303–2.18% without MOET when 2, 5, 10 and 20 proven sires were used in the population. Schemes using 70% mating of young sires resulted in a shorter generation interval of 3.46 years in comparison with proven sires scheme with 4.06 years. Young sires breeding program yielded lower genetic gain from 420.1 SKK per year when 20 proven sires were used to 578.44 SKK per year when 2 proven bulls were selected in the population. Proven sires breeding program led to higher genetic gain from 400.17 SKK (with 20 proven bulls) to 629.72 SKK (2 proven bulls). In a group with 20 proven bulls young sires breeding program with MOET resulted in genetic gain 466.38 SKK comparable to young sires breeding program without MOET with 10 proven sires. In groups with 10 or 5 proven bulls this alternative led to the highest genetic gain 515.45 SKK and 565.25 SKK, respectively. A group with 2 proven bulls in MOET scheme achieved similar genetic gain (629.14 SKK) like the proven sires scheme.

Keywords: Pinzgau breed; gene flow; genetic gain; generation interval; inbreeding; milk

Cattle breeding programs are characterized by extensive performance tests, use of artificial insemination and computer-aided selection decisions. Depending on the population structure the implementation of these measures led to a considerable genetic improvement that ranged in the interval of 1–3% of the average performance of the population and year (Kalm, 1998). In breeding programs aimed at milk production genetic gain of 30–180 kg of milk per year can be anticipated (Přibyl *et al.*, 1997).

The nucleus breeding programs have been proposed for *in situ* conservation of small, endangered breeds. In cattle breeding two alternatives have been developed. The first one includes central herds with complete performance tests and embryo transfer from elite animals. The second alternative uses integrated MOET-nucleus-breeding programs with herd book enterprises (Kalm, 1998).

Slovak Pinzgau Association designed a breeding program. It is a traditional breeding program in which artificial insemination was accepted as a factor of intensification and increase in the animal selection reliability. Production conditions have changed and the size and structure of the Pinzgau breed have undergone considerable changes. Pinzgau breed ranked among the endangered populations. Due to these changes the structure of the Pinzgau breeding program does not take into account the situation of the breed any more.

In Austria MOET Pinzgau breeding program was designed (Gesser, 1992) with the aim to preserve the dual-purpose type of the breed. Gierzinger (1996) formulated a scheme modifying the program that used young bulls. Based on model calculations he found the optimum use of young bulls in the reproduction of the population fluctuating in the interval

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of 70–80%. Pinzgau breed in Austria has a special position that results from the population structure and low insemination intensity (65%). In theoretical calculations, MOET programs based on principles of closed nucleus result in the highest genetic gain, in practical breeding programs they are designed as open nucleus breeding programs. FAO recommended an open nucleus breeding program for *in situ* conservation of endangered populations (FAO, 1992).

An alternative of the international Pinzgau breeding program was analysed by Kasarda *et al.* (1999) where genetic gain of milk was observed as the main criterion. It resulted in a scheme with the use of 70% young sires in breeding program. By comparison of the costs in different alternatives of breeding program Kasarda *et al*. (2000) using a deterministic model concluded that young sires program was more effective than program with proven sires.

A change in the existing breeding program was recommended (Kadlečík *et al.*, 1998; Mildner *et al.*, 1999; Kasarda *et al.*, 2000). Kasarda *et al.* (2002) evaluated the systems of proven bulls, young bulls and MOET in the Pinzgau breeding program using truncation selection (Bichard *et al.*, 1973; Ducrocq and Quass, 1988). Gene flow with overlapping generations (Hill, 1974; Brascamp, 1975), long-term genetic contributions (Woolliams, 1998; Woolliams *et al.*, 1999; Bijma and Woolliams, 2000), decrease in variability due to Bulmer equilibrium (Bulmer, 1971) as well as fixed proportions of used animal age classes were taken into account. According to Meuwissen (1990), Villanueva *et al.* (1993), Bijma and Rutten (2002) a decrease in variability due to Bulmer equilibrium is tending to asymptotic value in-between 6th generations. Bulmer equilibrium decreases variability of selection index by 20–30% (Bulmer, 1971; Meuwissen, 1990) or by 8–26% (Villanueva *et al.*, 1993).

The aim of this paper was to assess genetic gain, generation interval and inbreeding rate in three alternatives of Pinzgau breeding program.

MATERIAL AND METHODS

Three alternatives of using bulls in the Pinzgau breeding program were designed (Kadlečík *et al.*, 1998). The analysis was based on expected genetic gain (ΔG), generation interval length (L) and increase in inbreeding rate per generation interval (ΔF) in groups using 2, 5, 10 and 20 proven bulls in the mating scheme. Rate of inbreeding was approximated in the population with discrete generations that had the same number of sires and dams per generation like in the case of overlapping generation model as well as index of the age class where the majority of parents was selected (Bijma and Rutten, 2002). The selection index (Hazel, 1943) was configured for 3 traits: milk production in kilograms (kg M), fat in kilograms (kg F) and protein in kilograms (kg P). The economic value was based on economic importance of the above-mentioned traits (Huba *et al*., 2001). Definitions of input parameters are in Table 1. The genetic gain was calculated after reaching Bulmer equilibrium (Bulmer, 1971). The selection index was configured using information on the own performance of cows, performance of half-sibs, full-sibs and offspring. Depending on the alternatives of the breeding program, information sources were used which contributed to the accuracy of breeding value and genetic gain prediction. Milk, protein and fat production were characterized on the basis of the results of official genetic assessment carried out by the State Breeding Institute of the Slovak Republic (SBI SR, 2001, Table 1). Computer program SelAction (Bijma and Rutten, 2002) was used for the analysis of all breeding program alternatives.

General assumptions taken into consideration:

Table 1. Input parameters for traits included in selection index according to results of milk recording system and economic weights of those traits (SBI SR, 2001; Huba *et al.*, 2001)

Trait	σ^2_P (kg)	EV (SKK)
Milk (kg)	613 606	0.08
Fat (kg)	1 142	42.24
Protein (kg)	699	128.92

Active population of 15 000 cows

Base for selection of bull mothers is 9 000 cows (–40% are selected for other reasons than for the breeding aim)

Correction of the length of calving interval 365/400 = 0.9125

No. of bull mothers selected 150 × 0.9125

No. of progeny 137

No. of male progeny 68

Intensity of selection in a rearing house –60%; intensity of selection at an AI station –10%

No. of bulls in progeny test 24 per year

Insemination index 2.2 ID

Bull fathers are only proven bulls
Reduction in No. of heifers to cows –35%
Reduction in No. of daughters with lactation – 20%

Alternatives of using bulls in the breeding program:

Alternative 1. Breeding program using 70% of proven sires and 30% of young sires

Bulls are selected first in age class 1 (one year old at the birth of progeny) for their pedigree information. In the second age class information on production of half-sibs becomes available. In the fifth age class progeny production information becomes available. Each test bull will have at least 48 daughters with closed lactation in the milk recording system. Young bulls undergoing test and proven bulls were used in the breeding program for one year. There will be need for approximately 400 ID per test bull. Numbers of animals considered in the breeding program are in Table 2. Gene flow matrix is designed for 5 age classes of bulls and 11 age classes of dams. Dams are selected first in age class one for their pedigree information. In the second age class information on own production and production of half-sibs based on milk traits becomes available. It is considered that there will be 30% of replacement cows each year.

Alternative 2. Breeding program using 70% of young sires and 30% of proven sires

Bulls are selected first in age class 1 for their pedigree information. In the second age class information on production of half-sibs becomes available. In the fifth age class progeny production information becomes available. Young bulls undergoing test and proven bulls were used in the breeding program for one year. Each test bull will have at least 113 daughters. Approximately 950 ID per test bull will be needed. Numbers of animals considered in the breeding program are in Table 3. Gene flow matrix is designed for 5 age classes of bulls and 11 age classes of dams. Dams are selected first in age class one for their pedigree information. In the second age class information on own production and production of half-sibs based on milk traits becomes available. It is considered that there will be 30% of replacement cows each year.

Alternative 3. Breeding program using 70% of young sires and 30% of proven sires with the use of MOET

Bulls are selected first in age class 1 (one year old at the birth of progeny) for their pedigree information. In the second age class information on production of half-sibs and 2 full-sibs becomes available. In the fifth age class progeny production information becomes available. Young bulls undergoing test and proven bulls were used in the breeding program for one year. Each test bull will have at least 48 daughters. Approximately 400 ID per test bull will be needed. Considered was the use of 150 donors with production of 5 embryos each, which means 750 recipient cows. Expected was 50% success with 375 progenies and half of them 150 bull calves (each bull mother has at least one male progeny for selection). No correction on calving interval was accounted for. In total 2 full-sibs of each sire were considered to contribute with information on milk production. Numbers of animals considered in the breeding program are in Table 4. Gene flow matrix is designed for 5 age classes of bulls and

Table 2. Number of animals considered in a breeding program using 70% of proven sires and 30% of young sires

	Number of proven bulls in group			
	2	5	10	20
No. of daughters, HS	1 351	540	270	135
No. of ID per proven bull	11 430	4 570	2 290	1 140

Table 3. Number of animals considered in a breeding program using 70% of young sires and 30% of proven sires

	Number of proven bulls in group			
	2	5	10	20
No. of daughters, HS	579	231	116	57
No. of ID per proven bull	4 900	1 960	980	490

Table 4. Number of animals considered in a breeding program using 70% of young sires and 30% of proven sires with the use of MOET

	Number of proven bulls in group			
	2	5	10	20
No. of daughters, HS	647	259	129	64
No. of ID per proven bull	4 650	1 860	930	450

11 age classes of dams. Dams are selected first in age class one for their pedigree information. In the second age class information on own production, production of half-sibs and 2 full-sibs based on milk traits becomes available. It is considered that there will be 30% of replacement cows each year.

RESULTS AND DISCUSSION

A decrease in selection intensity (by increasing the number of used proven bulls) causes a decrease in genetic gain in natural and also in monetary units in all alternatives of the program (Table 5). A decrease in proven bulls' selection intensity also decreases inbreeding rate per generation interval. Generation interval in alternatives 2 and 3 with the use of 70% of young sires to breed dams was shorter than in alternative 1 with the use of 70% of old proven sires with difference 0.5 year. Selection of 2 proven sires in the breeding program, alternative 1, led to the highest genetic gain; the difference in comparison with alternative 2 is 8%. In comparison with alternative 3, the difference was 0.60 SKK, which means that genetic gain in alternative 1 was higher by 0.001% than in alternative 3. Breeding program with 5 proven bulls in alternative 3 (with the use of MOET) became leading. Genetic gain in alternative 1 was lower by 4.4% than in alternative 3. The difference in genetic gain between alternative 2 and alternative 3 was 8.9%. When 10 proven bulls were used in the breeding program, the advance of alternative 3 became more significant in comparison with alternative 1, the difference was 8.4% and against alternative 2 it was 9.3%. The use of 20 proven sires in alternative 1 – scheme with the use of 70% of proven sires in the breeding program, resulted in the lowest genetic gain, whereas alternative 2 led to genetic gain which was higher by 4.7% and in comparison with alternative 3 the advantage of young sires in MOET breeding program was 10%.

In all three alternatives the use of 2 proven sires per year in the breeding program led to an increase in the rate of inbreeding which was higher than 1%, according to the recommendation of Bodó (1992) it is the critical value for an endangered population. With 5 proven sires, only alternative 3 resulted in the rate of inbreeding higher than 1% but the difference from the recommended value was not significantly larger (+0.019%). After including the criterion of the rate of inbreeding in a decision process it is advantageous to use the young sires breeding program, particularly in combination with MOET.

The accuracy of estimated breeding value (EBV) varied in the alternatives when different information sources were introduced into selection index (Table 5). In general pedigree information had a very low contribution to the reliability of EBV's from 5.4 to 15%. Pedigree information is available from the birth of the animal. In the second age class (two years old at the birth of progeny) for sires, information on production of its half-sibs becomes available, which increases reliability from 16% to 24.4%. For dams in the second age class information on their own milk production becomes available and also the information on production of their female half-sibs was considered. The reliability increased from 28.1% to 36.7% due to these information sources. With the use of MOET in alternative 3, and contribution of information on production of two full-sibs (available from the second age class) reliability from 32.4% to 39.4% could be achieved in dams. Full-sib's information adds 2.75% to 3.6% to the reliability of EBV through sires (available from the second age class). Highest reliability is achieved in the fifth age class where information on progeny becomes available and reaches theoretical possibilities. In alternative 1 we observed the highest reliability of EBV from 86.5% in the scheme with 20 proven sires to 98.4% when 2 proven sires were used. Alternative 2 with the use of 70% of young sires led to the lowest reliability of EBV from 75.2% to 96.3%. Reliability of breeding value observed in

Table 5. Genetic gain, increase in inbreeding per generation interval, generation interval of alternatives and changes in the accuracy of breeding value information depending on information sources in alternatives

Parameter		Alternative 1				Alternative 2				Alternative 3			
		2	5	10	20	2	5	10	20	2	5	10	20
Genetic gain	Milk (kg)	100.55	86.58	75.86	64.58	92.58	82.99	75.43	68.18	100.55	90.67	83.01	75.48
	Fat (kg)	3.67	3.14	2.73	2.30	3.36	2.97	2.70	2.43	3.66	3.27	2.97	2.66
	Protein (kg)	3.62	3.11	2.72	2.31	3.33	2.97	2.70	2.43	3.62	3.26	2.98	201.7
Selection index (Skk)		629.72	540.53	472.03	400.17	578.44	515.02	467.33	420.1	629.14	565.25	515.45	466.38
Inbreeding change/generation (%)		1.903	0.838	0.453	0.248	2.18	1.018	0.545	0.301	2.177	1.019	0.553	0.313
Generation interval (year)		4.06	4.06	4.06	4.06	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46
Accuracy of EBV													
Information source – Bulls	Pedigree	0.369	0.321	0.289	0.27	0.342	0.289	0.253	0.232	0.384	0.330	0.288	0.249
	HS	0.441	0.405	0.38	0.366	0.494	0.457	0.429	0.403				
	HS+FS									0.529	0.493	0.463	0.433
	Progeny	0.992	0.981	0.962	0.93	0.984	0.96	0.925	0.867	0.986	0.965	0.933	0.879
Information source – Cowa	Pedigree	0.369	0.321	0.289	0.27	0.342	0.289	0.253	0.232	0.384	0.330	0.288	0.249
	OP+HS	0.57	0.55	0.533	0.527	0.606	0.582	0.566	0.534				
	OP+HS+FS									0.628	0.604	0.586	0.569

HS = half-sibs

HS+FS = half-sibs + full-sibs

OP+HS = own performance + half-sibs

OP+HS+FS = own performance + half-sibs + full-sibs

2, 5, 10, 20 = number of proven sires in group

Table 6. Changes in input parameters after reaching Bulmer equilibrium in the alternatives of breeding program

Parameter[1]		Input values	Alternative											
			1				2				3			
			2	5	10	20	2	5	10	20	2	5	10	20
	KgM	0.27	0.241	0.242	0.245	0.250	0.241	0.242	0.242	0.246	0.231	0.232	0.233	0.237
h^2	KgF	0.20	0.179	0.180	0.182	0.186	0.179	0.180	0.180	0.182	0.171	0.172	0.172	0.175
	KgP	0.24	0.206	0.207	0.211	0.216	0.206	0.207	0.207	0.212	0.194	0.195	0.196	0.201
	KgM-KgF	0.70	0.691	0.691	0.692	0.694	0.691	0.691	0.691	0.692	0.687	0.688	0.688	0.689
r_P	KgM-KgP	0.90	0.896	0.896	0.896	0.897	0.896	0.896	0.896	0.897	0.894	0.895	0.895	0.895
	KgF-KgP	0.80	0.794	0.794	0.795	0.796	0.794	0.794	0.794	0.795	0.792	0.792	0.792	0.793
	KgM-KgF	0.73	0.689	0.690	0.694	0.702	0.688	0.690	0.690	0.696	0.671	0.672	0.674	0.68
r_G	KgM-KgP	0.85	0.823	0.824	0.827	0.832	0.823	0.824	0.824	0.828	0.812	0.813	0.814	0.818
	KgF-KgP	0.75	0.708	0.709	0.714	0.722	0.707	0.709	0.709	0.715	0.689	0.690	0.692	0.699

h^2 = heritability; r_P = phenotypic correlation; r_G = genetic correlation; KgM = milk in kg; KgF = fat in kg; KgP = protein in kg; 2, 5, 10, 20 = number of proven bulls in group

the 3rd alternative was from 0.01% to 2.1% higher than in alternative 2. These differences depended mostly on the number of progeny contributing information to the sires (Tables 1, 2, 3).

In comparison with Bulmer (1971) we did not observe such a large decrease in selection index variability due to so called Bulmer equilibrium. We can agree with the results of Villanueva *et al.* (1993) that the observed decrease in heritability due to Bulmer equilibrium is higher (8–15%) than in phenotypic (1–2%) or genetic (4–8%) correlations between selection index traits (Table 6). The MOET program guarantees the conditions for maximum genetic gain prediction but also for the risk of maximum decrease in variability and increase in inbreeding in the population. The selection index included information on full-sibs as a result of using MOET in the population of cows. When using the animal model to assess the breeding value of individuals this information source improved the accuracy of breeding value prediction. This fact was also confirmed by Dekkers (1992).

In the young bulls system it is common in the field to mate a part of the population to elite sires. Niebel and Fewson (1978) found programs using young unproven bulls to present alternatives with higher genetic gains than do systems using mainly proven bulls. They considered young unproven bulls with 60% use in breeding to be the most suitable scheme. Robertson (1957) concluded that the share of young bulls in a breeding program should not surpass the limit of 70%. Gierzinger (1996) gives the optimum share of young bulls in breeding programs in the interval of 70–80%. Kadlečík *et al.* (1999) arrived at similar conclusions. Kasarda (2003) analysed an alternative of the use of 100% young sires in breeding of Pinzgau cattle with conventional and MOET breeding schemes. This alternative led to the lowest genetic gain, shortest generation interval and because of the absence of progeny test to the lowest accuracy of EBV. Breeding programs using progeny tests change towards the open nucleus breeding programs when MOET is used in the mothers of bulls. Breeding programs with an open breed nucleus are recommended for active conservation of endangered animal populations (FAO, 1992).

CONCLUSIONS

It follows from the results and their comparison that designing the strategy for dual-purpose

Pinzgau breed development it is suitable to use MOET's with a share of 70% of unproven and 30% of proven bulls. The use of 10–20 breeding bulls in reproduction can ensure a suitable genetic progress in the production of milk, fat and proteins, in the length of the generation interval as well an increase in inbreeding per generation interval below $\Delta F = 1\%$. For realization of this breeding program strong economic support on the national and international level will be necessary.

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ABSTRAKT

Genetický zisk, prírastok inbrídingu a generačný interval v alternatívach šľachtiteľského programu

Cieľom práce bolo analyzovať alternatívy šľachtiteľského programu slovenského pinzgauského plemena. Alternatívy boli optimalizované podľa ročného genetického zisku selekčného indexu zostaveného z ukazovateľov mliekovej úžitkovosti a prírastku inbrídingu za generačný interval. Schéma s využívaním 70 % preverených býkov v šľachtiteľskom programe viedla k nižšiemu prírastku inbrídingu za generačný interval od 0,248 % do 1,903 % ako schéma MOET s využívaním 70 % mladých nepreverených býkov s prírastkom od 0,313 % do 2,177 %, resp. schéma bez použitia MOET s prírastkom inbrídingu 0,303 % až 2,18 % za generáciu pri použití 2, 5, 10, resp. 20 preverených býkov v populácii. Schémy s využívaním 70 % mladých nepreverených býkov viedli ku kratšiemu generačnému intervalu 3,46 roka v porovnaní so schémou s využívaním 70 % preverených býkov v populácii 4,06 roka. V programe s využívaním 70 % mladých nepreverených býkov produkoval nižší zisk od 420,1 SK ak bolo využívaných 20 preverených býkov v programe do 578,44 SK za rok ak boli využívané dva preverené býky v porovnaní s ostatnými alternatívami. Program s využívaním 70 % preverených býkov viedol k dosahovaniu vyššieho genetického zisku od 400,17 SK (s 20 preverenými býkmi v skupine) do 629,72 SK (dva preverení býci). MOET šľachtiteľský program s využívaním 70 % mladých býkov predstavoval v skupine s 20 preverenými býkmi porovnateľný genetický zisk 466,38 SK ako zisk dosiahnutý v skupine s 10 preverenými býkmi v schéme bez použitia MOET. V skupine s 5, resp. 10 preverenými býkmi viedla schéma s použitím MOET k najvyššiemu genetickému zisku 515,45 SK, resp. 565,25 SK. V skupine s dvoma preverenými býkmi produkovala schéma s MOET porovnateľný genetický zisk 629,14 SK ako schéma šľachtiteľského programu s využívaním 70 % preverených býkov.

Kľúčové slová: Pinzgauský dobytok; tok génov; genetický zisk; generačný interval; inbríding; mlieko

Corresponding Author

Ing. Radovan Kasarda, PhD., Slovak Agricultural University, Department of Genetics and Breeding Biology, A. Hlinku 2, 949 01 Nitra, Slovak Republic
E-mail: radovan.kasarda@uniag.sk