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# Genetic and economic evaluation of genetic improvement schemes in pigs

## I. Methodology with an application to a three-way crossbreeding scheme

*Dedicated to Professor Dr. Peter Glodek on the occasion of his 65$^{th}$ birthday*

## Summary

A method is presented for evaluating selection strategies for a three-way cross in pigs. Multitrait selection is considered. The criteria of evaluation are the annual genetic gains in the breeding objective and its component traits, and the profit which is the net present value of return from investment in the scheme.
Selection in the sire line (Pietrain) contributes higher returns than selection in the dam lines. Meat percentage is the dominant trait in the sire line and has the highest impact on the breeding objective. The sire line is characterised by a negligible economic weight for the reproduction trait and has higher weights than dam lines for growth and carcass traits. The higher discounted economic values of these traits for Pietrain compared to those for dam lines deviate considerably from the equal weighting often applied in practical breeding programmes.

Key Words: genetic and economic evaluation, selection schemes, pig, crossbreeding, performance testing

## Zusammenfassung

Titel der Arbeit: **Genetische und ökonomische Beurteilung von Zuchtplänen beim Schwein. 1. Mitt.: Methode und Anwendung für eine Dreirassenkreuzung**
Ein Verfahren für die Beurteilung von Zuchtplänen wird am Beispiel einer Dreirassenkreuzung beim Schwein vorgestellt. Die Vergleichskriterien sind die jährlichen Zuchtfortschritte der Zuchtzielmerkmale und der Züchtungsgewinn.
In der Vaterrasse (Pietrain) werden höhere Züchtungserträge erzielt als in den Mutterassen. Der Muskelfleischanteil ist das dominante Merkmal in der Vaterrasse und besitzt den größten Einfluß auf das Zuchtziel. Die Vaterrasse ist charakterisiert durch ein zu vernachlässigendes ökonomisches Gewicht für das Reproduktionsmerkmal und besitzt höhere ökonomische Gewichte für die Merkmale der Mastleistung und des Schlachtkörperwertes. Die höheren diskontierten Grenznutzen dieser Merkmale beim Pietrain im Vergleich zu den Mutterrassen weichen beträchtlich von einer gleichen Gewichtung ab, wie sie häufig in Zuchtprogrammen praktiziert wird.

Schlüsselwörter: Genetische und ökonomische Beurteilung, Zuchtpläne, Schwein, Kreuzungszucht, Leistungsprüfung

## 1. Introduction

Genetic improvement of a population through selection is the main task of animal breeding. The aim is to select the population towards a well-defined breeding objective which suits the future production/marketing requirements of the average commercial producer. This aim should be achieved fast and be economically efficient. Thus, the criteria used to evaluate a genetic improvement scheme are the annual genetic response for the breeding objective and the profit or net return from invested money.

Applying the formula of RENDEL and ROBERTSON (1950) a large number of studies investigated how to maximize the annual genetic gain (SKJERVOLD, 1963; SKJERVOLD and LANGHOLZ, 1964; NICHOLAS and SMITH, 1983). Although the basis of formulating a multitrait breeding objective (the "aggregate genotype") had been demonstrated long before (HAZEL, 1943), most of these aimed at selecting for a single trait. This holds particularly when a stochastic simulation approach rather than a deterministic procedure has been used (e.g. RUANE and THOMPSON, 1991). Although these studies present some basic recommendations, they are less appropriate for investigating breeding schemes in practice where the aim is usually to improve an aggregate breeding objective comprising all economically important traits.
There is still a great lack of a clear definition of the breeding objective under most circumstances. This is due to a widespread lack of cooperation between geneticists and economists. This lack of cooperation may also be the main reason why very little has been done in regard to cost/benefit analysis of breeding schemes. A methodology will be introduced which covers both evaluating the annual genetic gain for an aggregate breeding objective as well as returns and profit from the breeding scheme. For these calculations the computer program ZPLAN was used which has been developed for this purpose (KARRAS et al., 1993). The method is demonstrated for an example consisting of a three-way crossbreeding scheme in pigs in Saxony (Germany) with Pietrain as the sire line, and German Landrace and Large White as the dam lines. Basic assumptions about population structure, selection groups, criteria of selection and costs will be given. The aim of this paper is to present these assumptions and the results of a basic breeding scheme. These concern the distribution of the testing capacity at the central test station as well as the extent of the field test, the contribution of the breeds to both monetary genetic gain and return and the economic weights of traits in the three breeds involved. In a second paper, these assumptions will be modified in order to optimise the basic situation and simulate various testing strategies of boars in the field as well as at the central station.

## 2. Material and Method

### Computer program

The approch used in this study for predicting the annual genetic gain is deterministic. One round of selection is considered with its impact on a given time horizon with specific discount rates. All selection groups in the whole population are to be defined, each with a specific selection intensity and with particular sources of information for index selection including two-stage selection. The ZPLAN program applies the gene-flow method described by MC CLINTOCK and CUNNINGHAM (1974), HILL (1974) and ELSEN and MOCQUOT (1974) to calculate the number of standard discounted expressions (SDE-values) for each trait in each selection group. This is required to get both correctly discounted economic weights for the objective traits and the discounted return over the given investment period. Fixed and variable costs are assumed for certain breeding efforts and used to derive the profit which is the return

minus costs. Return, cost and profit is expressed per sow in the total population. The program has been used to evaluate different genetic improvement schemes by GRASER et al. (1994) for beef cattle, by RIEDL (1996) for dairy cattle and by MUELLER (1995) and KOMINAKIS et al. (1997) for sheep.
For this study, the three purebred lines, the $F_1$-sows and the terminal products are considered. Through weighting the economic values with the SDE-values, the different breeding goals for each breed involved are taken into account. Using selection index procedures the program enables the analysis of different breeding schemes for a defined investment period with respect to maximising monetary genetic gain and profit. Simulating selection strategies using different herd and population structures, testing capacities and selection intensities for performance traits, the program realises a multi-trait genetic and economic optimisation of breeding schemes. Further details are given in NITTER et al. (1994).

**Population structure**

The Saxonian pig breeding scheme consists of different levels in a pyramid described as nucleus, multiplier and commercial level. The breeding enterprise needs information in order to optimise mating, selection and management decisions for all breeds used in the three-way cross breeding scheme. The German Landrace breed (GL) currently consists of 4000 sows, including 800 nucleus sows and 3200 multiplier sows. The Large White breed (LW) with 100 sows is used similarly to GL as a dam line. Pietrain (Pi) with 125 sows is the sire line. The $F_1$-generation (LW x GL) contains 46000 sows.

| | NB_GL | NS_GL | NB_LW | NS_LW | NB_Pi | NS_Pi | PS_$F_1$ |
|---|---|---|---|---|---|---|---|
| NB_GL | 1 | 2 | | | | | |
| NS_GL | 3 | 4 | | | | | |
| NB_LW | | | 5 | 6 | | | |
| NS_LW | | | 7 | 8 | | | |
| NB_Pi | | | | | 9 | 10 | |
| NS_Pi | | | | | 11 | 12 | |
| PS_$F_1$ | | 13 | 14 | | | | |
| TP | | | | | 15 | | 16 |

NB = nucleus boars; GL = German Landrace; NS = nucleus sows; LW = Large White; PS = production sows; Pi = Pietrain; $F_1$ = $F_1$-generation (LW x GL); TP = terminal products (Pi (LW x GL)); > = produce; 1, 5, 9 = nucleus boars > nucleus boars; 2, 6, 10 = nucleus sows > nucleus boars; 3, 7, 11 = nucleus boars > nucleus sows; 4, 8, 12 = nucleus sows > nucleus sows; 13 = nucleus sows > production sows; 14 = nucleus boars > production sows; 15 = nucleus boars > terminal products; 16 = production sows > terminal products

Fig.: Transmission matrix of the three-way cross with 16 selection groups. Origin of parents (gene donors) in columns, offspring (gene recipients) in rows (Übertragungsmatrix der Dreiwegekreuzung mit 16 Selektionsgruppen. Abstammung der Eltern (Genspender) in den Spalten, der Nachkommen (Genempfänger) in den Reihen)

## Selection groups

The Figure shows the 16 selection groups in the transmission matrix of the gene flow method described by HILL (1974) and ELSEN and MOCQUOT (1974). Twelve selection groups are defined in the nucleus units, where boar selection occurs both to improve boars (boars to breed boars, NB>NB) and females (boars to breed sows, NB>NS). Selection of females in the nucleus also intends to improve boars (sows to breed boars, NS>NB) and females (sows to breed sows, NS>NS). These groups describe the four-path model used and are reflected in the three purebred blocks (GL 1-4, LW 4-8, Pi 9-12). In the Figure is also clearly shown that nucleus sows of GL (NS>PS, 13) produce the production sows (e.g. $F_1$-generation of sows) after mating with LW-sires (NB>PS, 14). No reciprocal crossing is assumed. The $F_1$-sows (PS>TP, 16) again generate the terminal products (e.g. slaughter pigs) after mating with the terminal Pietrain sires (NB>TP, 15).

Table 1

Sources of information for selection in various selection groups and selection steps (Informationsquellen für die Selektion der verschiedenen Selektionsgruppen und Selektionsstufen)

| Selection group | Genetic group | Information source | Field / Station | No. of animals | No. of litters | Recorded traits |
|---|---|---|---|---|---|---|
| Boars, 1st selection step | all | Ind, F, FF | F | 1 | | ADG, US |
| | | M | F | 1 | 1 | NBA, ADG, US |
| | | FM | F | 1 | 3 | NBA, ADG, US |
| | | FS F | S | 2 | | DG, LMP, FE, $pH_1$ |
| | GL | HS F | F | 60 | 1 | NBA |
| | LW, Pi | HS F | F | 10 | 1 | NBA |
| | all | HS F | S | calc.‡ | | DG, LMP, FE, $pH_1$ |
| | GL | HS M | F | 60 | 1 | NBA |
| | LW, Pi | HS M | F | 10 | 1 | NBA |
| | all | HS M | S | calc. | | DG, LMP, FE, $pH_1$ |
| | all | HS Ind | S | calc. | | DG, LMP, FE, $pH_1$ |
| Boars, 2nd selection step† | GL | Progeny | S | calc. | | DG, LMP, FE, $pH_1$ |
| | $LW_P$ | Progeny | S | calc. | | DG, LMP, FE, $pH_1$ |
| | $LW_C$ | Progeny | F | calc. | | LMP, $pH_1$, ADG |
| | $Pi_P$ | Progeny | S | calc. | | DG, LMP, FE, $pH_1$ |
| | $Pi_C$ | Progeny | F | calc. | | LMP, $pH_1$, ADG |
| Gilts, 1st selection step | all | Ind | F | 1 | | ADG, US |
| | | F, FF | F | 1 | | ADG, US |
| | | M | F | 1 | 1 | NBA, ADG, US |
| | | MM | F | 1 | 3 | NBA, ADG, US |
| Sows, 2nd selection step† | all | Ind | F | 1 | 1 | NBA |

† additional to information of first selection step; ‡ calculated; Ind = self performance; F = father; FF = father's father; M = mother; FM = father's mother; FS F = full sib's of father; HS F = half sib's of father; HS M = half sib's of mother; HS Ind = half sib's of proband (paternal); DG = daily gain (test period); NBA = number of piglets born alive; LMP = meat percentage; ADG = average daily gain (life time); FE = feed efficiency; US = ultrasonic side-fat thickness; $pH_1$ = pH-value (45 min.); GL = German Landrace; LW = Large White; Pi = Pietrain; $LW_P$ = Large White boars mated with Large White sows; $LW_C$ = Large White boars mated with German Landrace sows to produce the $F_1$-generation; $Pi_P$ = Pietrain boars mated with Pietrain sows; $Pi_C$ = Pietrain boars mated with $F_1$-generation to produce the terminal products

## Selection criteria

Sources of information for selection in the different selection groups are shown in Table 1. Within a breed, they are identical for boars in the first stage, independent of the kind of later use for mating (purebred or crossbred). The number of relatives assumed to have records in the various selection groups depends on parameters such as boar to sow ratio, survival rates and data recording. This explains that in GL more recordings are available for selection than in the other two lines.

Selection at the nucleus level for production as well as for reproductive traits takes place in two stages. In the first step, the animals are selected upon data from the performance test of the animal itself and its ancestors with additional full- and half-sib information. In a second selection step the best boars in the self-performance test are progeny tested at the station (purebred matings) and in the field (crossbred matings) to select the boars for replacement of the nucleus boars. Boars serving merely to produce crossbreds are tested only in the field. At the station a boar is tested with 4 progeny groups. Each group consists of 2 piglets per litter of the same sex (male in GL, females in LW and Pi). The animals are kept in group housing and the feed efficiency is measured individually. For testing under field conditions, the group size is assumed to consist of 6 slaughtered animals per successful mating. The evaluation takes place with completion of the progeny test. For sows, the number of piglets born alive (NBA) in the first litter is the criterion in the second selection stage.

In Table 2, the selection criteria are listed with their phenotypic standard deviations, heritabilities and phenotypic/genetic correlations. Standard deviations differ between dam and sire lines according to recent findings in Saxony (MUELLER, 1997). Furthermore, for the five traits included in the breeding objective, the non-discounted economic values derived on commercial level are shown. They have been calculated as the difference between the additional revenue and additional costs from increasing the trait by one unit and were referred to one piglet basis.

Table 2

Traits and their non discounted economic values (v), heritabilities ($h^2$), phenotypic standard deviations ($\sigma_P$) and phenotypic and genetic correlations (phenotypic correlations above and genetic correlations below the diagonal) (Merkmale und ihre undiskontierten Grenznutzen (v), Heritabilitäten ($h^2$), phänotypische Standardabweichungen ($\sigma_P$) und phänotypische und genetische Korrelationen (phänotypische Korrelationen oberhalb, genetische Korrelationen unterhalb der Diagonale)) †

| Trait | Unit | $h^2$ | $\sigma_P$ | | v | Genetic and phenotypic correlations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | GL, LW | Pi | DM | DG | LMP | FE | $pH_1$ | NBA | ADG | US |
| DG | g/d | .35 | 95 | 85 | .11 | - | -.15 | -.55 | -.15 | 0 | .40 | .20 |
| LMP | % | .55 | 2.2 | 2.3 | 4.5 | -.20 | - | -.15 | -.30 | 0 | 0 | -.30 |
| FE | kg/kg | .35 | .24 | .16 | -36 | -.65 | -.20 | - | .05 | 0 | -.20 | 0 |
| $pH_1$ | .1 | .20 | .20 | .18 | 2.0 | -.25 | -.35 | .05 | - | 0 | -.15 | .10 |
| NBA | piglets | .10 | 2.0 | 1.7 | 7.5 | .10 | 0 | 0 | 0 | - | 0 | 0 |
| ADG | g/d | .20 | 45 | 50 | - | .50 | 0 | -.30 | -.20 | .05 | - | 0 |
| US | mm | .25 | .15 | .12 | - | .30 | -.40 | .20 | .10 | 0 | .15 | - |

† for abbreviations, see footnote Table 1

In order to use purebred and crossbred information for estimating the breeding value of purebred sires, a connectedness is to establish for the traits measured on progeny tested animals at station and for those tested in the field (MUELLER and MIELENZ, 1986). Because correlations of the same trait in pure- and crossbreeding progeny are not unity, they have to be considered as two traits. Assumed correlations are given in Table 3 derived on the basis of estimations of BRANDT (1994). Newer results received more attention in which relationships between animals were considered in detail and more animals were involved. Correlations of different traits between pure- and crossbreds were derived according to the model of path coefficients (WRIGHT, 1934) as published estimates are mainly related to correlations of the same trait. Resulting genetic and phenotypic matrices were checked with the computer program MATDEF (MIELENZ and WAGENKNECHT, 1992) to ensure that they were positive definite. In case of non-positiveness the program determines a positive definite matrix which has a minimum distance to a given non-positive matrix. This procedure makes it possible to include information of the progeny test in the field for the selection of purebred boars.

Table 3
Genetic correlations used between purebred and crossbred information (Verwendete genetische Korrelationen zwischen Reinzucht- und Kreuzungsleistungen)

| Traits | Large White - $F_1$ | | | Pietrain - end product |
|---|---|---|---|---|
| | Variant 1 | Variant 2 | Variant 3 | Variant 4 |
| DG | - | - | 0.8 | - |
| LMP | - | 0.7 | 0.9 | 0.7 |
| FE | - | - | 0.6 | - |
| $pH_1$ | - | 0.7 | 0.9 | 0.7 |
| NBA | 0.6 | - | - | - |
| ADG | 0.7 | 0.7 | 0.7 | 0.7 |
| US | 0.8 | - | 0.8 | - |

Variant 1: Large White self performance in the field to $F_1$ self performance in the field; variant 2: Large White progeny (purebred) at the station to Large White progeny (crossbred) in the field; variant 3: Large White progeny (purebred) at the station to Large White progeny (crossbred) at the station; variant 4: Pietrain progeny (purebred) at the station to Pietrain progeny (crossbred) in the field

## Biological and technological parameters

In Table 4 biological and technological parameters are listed for the basic situation. Usual lengths of productive lifetime for boars and sows in the different levels were assumed. To compare productive lifetimes, attention has to be paid to the time for the first use of boars and sows for matings. Table 4 shows that boars after the self-performance test at an age of 11 months (1st selection step) are already used to breed purebred sows and crossbreds. After the completion of the progeny test at an age of 22 months (2nd selection step) they breed purebred boars after being mated with progeny tested sows (planned matings). Planned matings are also assumed for sows to produce boars. In the multiplier and the production levels a very wide boar to sow ratio is assumed due to the high percentage of artificial inseminations in Saxony. This circumstance enables higher selection intensity for boars used to produce crossbreds. Furthermore, a reduction of selection intensity occurs because 15 % of the boars are not suitable for artificial insemination and an additional 20 % do not survive until completion of the progeny test. Finally, 20 % of selected gilts are also not available for breeding because of no pregnancy.

Table 4
Biological and technological parameters for the basic situation (Biologische und technologische Parameter der Ausgangssituation)

| | | Selection step | |
|---|---|---|---|
| Age of animal when first litter is born (months) | | First | Second |
| Boar sires | | - | 22 |
| Sow sires | | 11 | - |
| Boar dams | | - | 17 |
| Sow dams | | 11 | - |
| Productive lifetime (months) | | | |
| Boar sires | | - | 12 |
| Sow sires in the nucleus unit | | 11 | 12 |
| Sow sires in the multiplier level | | 11 | 18 |
| Sow sires in the production level | | 11 | 24 |
| Boar dams | | - | 14 |
| Sow dams in the nucleus unit | | 6 | 14 |
| Sow dams in the multiplier level | | 6 | 18 |
| Sow dams in the commercial level | | 36 | - |
| Boar to sow ratio | | | |
| Purebreds | - German Landrace | 1 : 40 | |
| | - Large White | 1 : 20 | |
| | - Pietrain | 1 : 20 | |
| Multiplier level | | 1 : 160 | |
| Commercial level | | 1 : 330 | |
| Survival and reproduction | | | |
| Time between births (months) | | 5.5 | |
| Self performance tested boars (number per year) | | | |
| | - German Landrace | 80 | |
| | - Large White | 70 | |
| | - Pietrain | 200 | |
| Losses of boars during self performance test at station (%) | | 25 | |
| Boars suitable for artificial insemination (%) | | 85 | |
| Losses of boars until completed progeny test (%) | | 20 | |
| Rate of pregnancy (%) | | 80 | |

## Investment parameters and costs

Investment parameters and costs are necessary to take the economic side of the breeding programme into account. Changing the investment parameters would have an effect on the SDE-values and thus on return, because they also affect the economic weights of traits in the breeding objective. Variable and fixed costs, however, affect neither returns nor genetic response. But investment parameters and costs both influence the profit. The investment parameters used as well as fixed and variable costs are shown in Table 5. Not included are costs occurring in the usual production process regardless of the recording scheme. Fixed costs include overhead costs to maintain the breeding programme. Variable costs are costs directly related to performance and pedigree recording. They are multiplied by the number of animals incurring these costs and occur mainly in the nucleus unit. Also shown in Table 5 is the time of occurrence of variable cost, which has to be taken into account.

Table 5
Investment parameters and costs (Investitionsparameter und Kosten)

| | | |
|---|---|---|
| Investment parameters | | |
| Investment period (years) | 10 | |
| Interest rate for returns (%) | 6 | |
| Interest rate for costs (%) | 4 | |
| Fixed and variable breeding costs (DM) | | |
| Fixed costs per year | 420 750.- | |
| Progeny test of boars - per sow and litter | 30.- | (.3)† |
| Progeny test of boars - per piglet | 7.50 | (.3) |
| Station test per animal | 130.- | (.4) |
| Slaughtering an animal at station | 35.- | (.6) |
| Self performance test of an animal in the field | 12.- | (.6) |
| Breeding performance test per sow | 20.- | (1.) |
| Additional costs for a purchased boar from outside the breeding area | 1500.- | (.6) |
| Proportional costs for housing a boar during the progeny test at the station | 600.- | (1.4) |

† average time of occurrence (in years), i.e. the difference between the time of birth of selected animals and the time of occurrence.

## 3. Results and Discussion

### Distribution of the test station capacity

Table 6 shows the distribution of the testing capacity for various genetic groups in the breeding scheme. The figures are obtained by varying the number of tested boars under a given number of tested groups per boar and tested animals per group with respect to maximise the profit. For evaluating young boars in the self-performance test, information from tested full- and half-sibs at station are taken into account. The GL breed claims the highest proportion of the capacity of the central test station with 43 percent through 36 tested boars. In Pietrain, nearly 31 boars and in LW approximately 17 boars should be tested per year. The small number of station tested animals in LW is also due to the decreased selection intensity in sow selection, because female piglets tested on station are lost for breeding. As expected, Pietrain boars require the highest proportion of testing capacity in the field (75 % compared to 25 % for LW boars). This is attributable to the number of Pietrain boars needed for mating $F_1$ sows and the more than 14 times lower quantity of LW boar matings with GL sows to produce the $F_1$ generation.

### Genetic gains and returns

Table 7 demonstrates the different natural and monetary genetic gains and the contributions to the return of the three lines in this crossbreeding scheme. The trait NBA has a considerably higher genetic gain in the dam lines (.075 piglets in GL and

Table 6
Number of tested boars per year and tested animals per boar in station and field test as well as distribution of testing capacity after optimisation in number of testing boars (Anzahl getesteter Eber je Jahr und getesteter Tiere je Eber auf der Station und im Feld sowie die Verteilung der Testkapazität nach der Optimierung der Anzahl an Testeber)

| | GL | LW | Pi | $LW_C$ | $Pi_C$ |
|---|---|---|---|---|---|
| | Station | Station | Station | Field | Field |
| Number of boars tested | 36 | 17 | 31 | 26 | 79 |
| Animals per boar † | 8 (4) | 8 (4) | 8 (4) | 60 (10) | 60 (10) |
| Number of tested animals | 288 | 136 | 248 | 1560 | 4740 |
| Tested animals in percent within station and field | 43 | 20 | 37 | 25 | 75 |

$LW_C$ = Large White boars mated with German Landrace sows to produce the $F_1$-generation; $Pi_C$ = Pietrain boars mated with $F_1$-generation to produce the terminal products; † tested groups per boar in brackets

Table 7
Natural and monetary genetic gain per year, generation interval, return, costs and profit (Naturaler und monetärer Zuchtfortschritt je Jahr, Generationsintervall, Züchtungsertrag, Züchtungskosten und Züchtungsgewinn) †

| Parameter | Unit | GL | LW | Pi | Total |
|---|---|---|---|---|---|
| Natural genetic gain per year | | | | | |
| DG | g | 11.07 | 12.54 | 12.75 | |
| LMP | % | 0.183 | 0.303 | 0.495 | |
| FE | kg/kg | -0.030 | -0.039 | -0.033 | |
| $pH_1$ | .1 | -0.012 | -0.012 | -0.015 | |
| NBA | piglets | 0.075 | 0.072 | -0.006 | |
| ADG | g | 6.48 | 5.34 | 6.72 | |
| US | mm | -0.0024 | -0.0018 | -0.009 | |
| Mean generation interval | years | 1.82 | 1.83 | 1.81 | 1.82 |
| Monetary genetic gain per year | DM | 3.66 | 4.65 | 4.74 | 4.35 |
| Return for single traits | | | | | |
| DG | DM | 1.65 | 1.36 | 3.52 | 6.53 |
| LMP | DM | 1.02 | 1.67 | 6.31 | 9.00 |
| FE | DM | 1.38 | 1.39 | 3.00 | 5.77 |
| $pH_1$ | DM | -.03 | -.03 | -.09 | -.15 |
| NBA | DM | 1.46 | 1.25 | -.01 | 2.70 |
| Return, total | DM | 5.48 | 5.64 | 12.73 | 23.85 |
| Return, percent | % | 23 | 24 | 53 | |
| Costs, total | DM | | | | 12.83 |
| Profit | DM | | | | 11.02 |

† For abbreviations of traits, see footnote Table 1

.072 piglets in LW) than in the Pietrain breed (-.006 piglets). LW and Pietrain are superior in traits related to fattening performance and carcass quality traits. The main difference between these two lines is in LMP, for which Pietrain is superior with an annual genetic gain of .495 versus .303 percentage points in LW. This emphasises its

position as a sire line. The differences in the mean generation interval for purebred animals are very small. The higher monetary genetic gain in LW and Pietrain in spite of the small population size is explained by the inclusion of information from crossbred offspring in the evaluation of nucleus boars.
The three traits DG, LMP and FE contribute most to the total return. The returns in Pietrain are more than two times higher for DG and FE, and LMP is even more than three times superior than in the dam lines. For this reason, Pietrain contributes at a rate of more than 50 percent to the total return of 23.85 DM per sow in the investment period. In the dam lines, the returns are relatively balanced between most of the traits. The trait $pH_1$ has a very small and negative contribution to the return. After subtraction of the costs, the breeding scheme leads to a profit of 11.02 DM per sow.

**Economic weights**

Non-discounted economic values of the traits (shown in Table 2) were multiplied by the standardised discounted expressions (SDE-values) of the selection groups in the nucleus and averaged over the selection groups in a line. The resulting discounted economic values, using DG in GL as a reference point, are presented in Table 8. These clearly show that the sire line is characterised by a negligible value for NBA, because reproductive performance is realised only by a restricted number of purebred sows. On the other hand, fattening performance and carcass quality traits are expressed in a high number of crossbred descendants, so that for those traits the sire line obtains higher values than the dam lines.
The relative economic weights reflect the relative economic importance of each trait within a line. They were calculated through weighting the discounted economic values with the genetic standard deviation, summing up the results of a line and expressing them in percent. The weight of LMP is higher in the sire line than in the dam lines (39.2 % versus 27.8 and 25.1 % resp.), whereas the weight of NBA in the dam lines is high (29.4 and 35.8 %).

Table 8
Discounted economic values and economic weights of traits in the breeding goal for the breeds (Diskontierte Grenznutzen und ökonomische Gewichte der Zuchtzielmerkmale der Rassen)

| Trait † | Discounted economic values (DM/unit) | | | Relative economic weights (%) | | |
|---|---|---|---|---|---|---|
| | GL | LW | Pi | GL | LW | Pi |
| DG (g/d) | 0.11 | 0.06 | 0.19 | 23.3 | 21.5 | 33.2 |
| LMP (%) | 4.52 | 2.53 | 7.89 | 27.8 | 25.1 | 39.2 |
| FE (kg/kg) | -35.17 | -19.66 | -61.37 | 18.8 | 17.0 | 26.5 |
| $pH_1$ (.1) | 2.01 | 1.12 | 3.51 | 0.7 | 0.6 | 0.9 |
| NBA (piglets) | 12.38 | 9.31 | 0.09 | 29.4 | 35.8 | 0.2 |

† For abbreviations of traits, see footnote Table 1

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