Effects of different breeding plans on the genetic gain in yield and non yield traits in dairy cattle.

Bengt Lindhé and Jan Philipsson
Department of animal breeding and genetics, SLU. Uppsala Sweden.

Introduction.

In a paper at the EAAP-conference in Prague Lindhé and Philipsson (1995) presented actual estimates of the genetic correlations between yield on one side and daughter fertility and disease resistance on the other for the Swedish dairy breeds SRB (Swedish Red and White) and SLB (Swedish Black and White). The effects on the estimated genetic gain on production as well as non-production traits were illustrated when zero genetic correlations were used instead of the "true" negative correlations. Generally, the estimated genetic gain was highly overestimated if zero genetic correlations were used. This was mostly pronounced for SLB with the most unfavourable correlations. Non production traits were more affected than yield. The effects on the weights (b-values) of the part indexes included were rather small.

In an other study Philipsson et al. (1994) illustrated that the relative genetic gains in yield and non yield traits were affected by the size of the progeny group. Pedersen and Christensen (1993) and Christensen (1994) have shown that the the design of the breeding plan has an effect on the relative genetic gain in different traits or groups of traits.

In conventional breeding programs for dairy cattle the proportion of young bull inseminations is a parameter which varies considerably between countries. In the Nordic countries the average level is relatively high and varies from about 30% in Denmark to 55% in Finland (Lindhé, 1995). In some countries the proportion of the cows inseminated with semen from young bulls is below 10%. Given the level of young bull inseminations, the available testing capacity can be used to test either many bulls with small daughter groups or fewer bulls with large daughter groups.

In the present paper the effects of different levels of young bull inseminations on the estimated genetic gain in yield and health and fertility traits are illustrated. Within each level the effect of varying number of tested bulls is shown.

The present paper also covers the effects of using heifers as bull dams in breeding schemes which are conventional in all other respects.

Methods used.

The breeding goal defined and all parameters in the index used for selection were the same as for the SRB-breed presented in the paper by Lindhé and Philipsson (1995). The traits and the parameters in the index are summarized in tables 1 and 2. For all traits the genetic standard deviation was standardized at s_a=7. In table 5 Protein yield was the sole variate recorded but the traits in the breeding goal and their economic weights remained unchanged.

The AI-breeding plan was assumed to fit a population of 700 000 recorded cows in AI (corresponding to the total number of recorded red cows in the Nordic countries). The traditional formula by Rendel and Robertson (1950) was used to calculate the genetic gain. Selection differentials were corrected for the finite number of selected animals.

Table 1. Traits and economic weights used in the calculation of the selection index.

Breeding goal Traits	Abbreviation	Economic weight per unit of subindex
Protein yield	Prot	1
Daughter fertility	Dfert	.30
Mastitis resistance	Mast	.30
Resistance Other diseases	Other	.15

Other abbreviations:
SS = the path sire to son.
SD = the path sire to daughter.
DS = the path dam to son.
DD = the path dam to daughter.
n = number of daughters in the progeny group.
PYBS = Proportion of young bull inseminations.
NYB = number of young bulls tested per year.
NSD = number of sires of cows.

Table 2. Heritabilities (diagonal, double underlines), genetic (above) and phenotypic correlations (below the diagonal) for the traits (=the variates) in the index calculations.

Trait/. Variate	Prot	Dfert	Mast	Other
Prot	.25	-.25	-.10	-.25
Dfert	-.035	.08	0	.30
Mast	-.009	0	.03	.20
Other	-.022	.015	.006	.03

In each path the gain in each of the traits was calculated by means of the regression of the part indexes on the total index. The sum of these gains of the part indexes were divided by the sum of the generation intervals as the sums of the gains in the total index were. No correction was made for the effect of inbreeding or of any possible Bulmer effect.

Conventional breeding plans.

In the SS-path 3 sires of bulls were selected from each annual crop of progeny tested bulls and used for two years. With these prerequisites generation interval used was 7.2 years. The selection of sires of sons was based solely on an index calculated with all the traits as observed variates and based on n daughters.

In the SD path selected bulls were used at an average of 75 000 inseminations in each of two years (total 150 000). The generation interval used was 7.2 years. In a population of 700 000 cows 1 015 000 females (cows and heifers) are annually inseminated. With 1.7 inseminations per female and 5% inseminations with beef semen the total volume of inseminations for young bulls and selected progeny tested bulls amounts to 1639225. The number of selected progeny tested bulls is thus a reflection of the proportion of inseminations with young bulls. The number of selected progeny tested bulls (NSD) amounts to

NSD=(1-PYBS)*1639225/150000;

The selection of sires of cows was based on the same index as was used for the sires of bulls.

It was assumed that 12 selected bull dams were needed to produce 1 son ready to be introduced as a young bull. This high number allows more diversity in pedigrees and culling of bulls at one year of age with respect to conformation, mating behaviour, bull fertility etc. Potential bull dams had sires and grandsires that at the time of insemination were progeny tested. This requirement reduced the number of potential bull dams as PYBS increased.

The bull dams were selected by means of an index comprising information on the protein yield of the cow itself in the first lactation, the same amount of information of the dam, an index of the sire with n daughters and an index of the MGS with 1000 daughters. (A bull with a second crop of daughters was assumed to have 1000 daughters). The generation interval in the DS path was given the value of 4.0 years. It is thus assumed that all bull dams had at least one lactation at the birth of their sons and that all first lactation cows with high pedigree indexes were mated to selected bull sires which allows the ones with high performance in the first lactation to be selected as bull dams by the time the second calf is born. It was assumed that on an average 10 inseminations in recorded herds were needed to produce one tested daughter out of young bulls.

Thus
NYB = PYBS*1639225/(10*n);

Proportion selected in the DD path amounted to 0.9. The generation interval in this path was calculated at 4.3 years.

Heifers as bull dams.

In table 6 the results are given for breeding plans at different PYBS-levels with n = 100. These breeding plans are identical with the ones used in table 3 and 4 with the following exceptions:

1. The number of potential bull dams was reduced by a factor of 0.75. (= The ratio of number of inseminated heifers to number of cows in the first and second lactation).
2. The generation interval in the path DS was set at 2.2 years.
3. The potential bull dams (heifers) were selected by means of a pedigree index comprising the protein yield of the dam and indexes of the sires and MGS based on n daughters.

Results.

Conventional breeding plans.

In table 3 DG in total merit index units and the number of young bulls tested per year are given for breeding plans where PYBS varies from 0.1 to 0.7 and n (the size of the daughter group) varies from 50 to 300.

The figures in table 3 confirm the early studies in AI-breeding plans (Skjervold and Langholz, 1964, Lindhé, 1968) that the optimum curves are very flat. The maximum point for DG is at a PYBS-level of 0.7 with 574 young bulls tested per year with 200 daughters each. However, 96% of that level or DG = 1.90 can be reached at a PYBS-level of 0.3 and with 492 bulls tested with 100 daughters each.

In table 4 the annual gain in Protein yield, Daughter fertility and resistance against Mastitis and Other diseases expressed in units of subindexes is given for the same alternative breeding plans as presented in table 3.

The highest levels for protein yield in each row (level of n) coincide with the highest levels for total DG in table 3. However in each column, which represent the PYBS-levels, the highest levels for protein yield are found at lower values of n (higher up in the table) than the highest levels for DG in table 3.

Table 3. DG in total merit and NYB for breeding plans where PYBS varies from 0.1 to 0.7 and n varies from 50 to 300. The highest DG:s in each row are underlined. Bold is used to indicate the highest DG in each column.

		PYBS				
n		0.1	0.3	0.4	0.5	0.7
50	DGtotal	1.74	1.84	1.86	1.86	1.83
	NYB	328	984	1311	1639	2295
75	DGtotal	1.76	1.89	1.91	1.92	1.90
	NYB	219	656	874	1093	1530
100	DGtotal	1.76	1.90	1.93	1.94	1.93
	NYB	164	492	656	820	1147
200	DGtotal	1.71	1.90	1.94	1.96	1.97
	NYB	82	246	328	410	574
300	DGtotal	1.65	1.87	1.91	1.94	1.97
	NYB	55	164	219	273	382

For Daughter fertility and resistance against Mastitis and Other diseases the highest values are found at the highest PYBS-level for all levels of n. For all PYBS-levels the highest values are found at the highest levels of n. When 30% of the cows are inseminated with young bulls the annual change in Dfert is -0.11 at a daughter group size of 50 but +0.06 at a daughter group size of 300. The size of the daughter group is by far the most important variable affecting the absolute and relative gain in non yield traits with negative genetic correlations with yield and with the economic weights given.

In table 5 indexes are used where Protein yield is the only vartiate recorded. The number of traits in the breeding goal are kept unchanged as well as the genetic correlations (the c-matrix is kept unchanged) and the economic weights.

When DGtotal in table 3 is compared with DG in Protein yield in table 5 it is obvious that the level of DG in Protein yield in table 5 is higher as selection is for yield alone. However, if the value of the deterioration in Dfert, Mast and Other is included, then the reverse is true. The conclusion is obvious. If the non yield traits have significant economic value and are negatively associated with yield they should be included in the index.

Table 4. Annual gain in index-units for Protein yield, Daughter fertility and resistance against Mastitis and Other diseases for the same breeding alternatives as in table 3. The highest values in each row is underlined. Bold is used to indicate the highest values in each column.

		PYBS				
n		0.1	0.3	0.4	0.5	0.7
50	Prot	1.79	1.89	1.91	1.91	1.87
	Dfert	-0.11	-0.11	-0.11	-0.10	-0.09
	Mast	0.04	0.05	0.05	0.05	0.05
	Other	-0.22	-0.22	-0.22	-0.22	-0.21
75	Prot	1.78	1.90	1.92	1.93	1.91
	Dfert	-0.06	-0.06	-0.05	-0.05	-0.04
	Mast	0.09	0.10	0.10	0.10	0.10
	Other	-0.17	-0.18	-0.18	-0.18	-0.17
100	Prot	1.76	1.89	1.92	1.93	1.91
	Dfert	-0.03	-0.02	-0.02	-0.02	-0.01
	Mast	0.12	0.13	0.14	0.14	0.14
	Other	-0.14	-0.15	-0.15	-0.14	-0.14
200	Prot	1.66	1.83	1.87	1.89	1.89
	Dfert	0.02	0.04	0.04	0.05	0.06
	Mast	0.19	0.22	0.22	0.23	0.24
	Other	-0.08	-0.08	-0.08	-0.07	-0.07
300	Prot	1.59	1.78	1.82	1.85	1.86
	Dfert	0.04	0.06	0.07	0.07	0.08
	Mast	0.21	0.25	0.26	0.27	0.28
	Other	-0.05	-0.05	-0.04	-0.04	-0.03

The most striking effect of including Dfert, Mast and Other in a total merit index is seen when the genetic changes in these part indexes in table 4 and 5 are compared. If they are included as in table 4 improvements can be seen in many combinations, especially when large daughter groups are used. If they are neglected as in table 5 severe deteriorations are unevitable.

Table 5. Effects of selection, DG in index units, when Protein yield is the only variate recorded.

n		PYBS 0.1	0.3	0.4	0.5	0.7
50	Prot	1.92	2.03	2.05	2.05	2.01
	Dfert	-0.48	-0.51	-0.51	-0.51	-0.50
	Mast	-0.19	-0.20	-0.20	-0.20	-0.20
	Other	-0.48	-0.51	-0.51	-0.51	-0.50
	DGtotal	1.64	1.74	1.75	1.76	1.72
75	Prot	1.92	2.06	2.08	2.09	2.07
	Dfert	-0.48	-0.51	-0.52	-0.52	-0.52
	Mast	-0.19	-0.21	-0.21	-0.21	-0.21
	Other	-0.48	-0.51	-0.52	-0.52	-0.52
	DGtotal	1.65	1.76	1.78	1.79	1.77
100	Prot	1.91	2.06	2.09	2.10	2.09
	Dfert	-0.48	-0.51	-0.52	-0.53	-0.52
	Mast	-0.19	-0.21	-0.21	-0.21	-0.21
	Other	-0.48	-0.51	-0.52	-0.53	-0.52
	DGtotal	1.63	1.77	1.79	1.80	1.79
200	Prot	1.83	2.02	2.06	2.08	2.09
	Dfert	-0.46	-0.51	-0.51	-0.52	-0.52
	Mast	-0.18	-0.20	-0.21	-0.21	-0.21
	Other	-0.46	-0.51	-0.51	-0.52	-0.52
	DGtotal	1.57	1.73	1.77	1.79	1.79
300	Prot	1.75	1.98	2.02	2.05	2.07
	Dfert	-0.44	-0.49	-0.51	-0.51	-0.52
	Mast	-0.18	-0.20	-0.20	-0.20	-0.21
	Other	-0.44	-0.49	-0.51	-0.51	-0.52
	DGtotal	1.50	1.69	1.73	1.76	1.78

Conventional breeding plans, heifers as bull dams.

In table 6 the effects of using heifers as bull dams is illustrated. In the alternative chosen the bull dams are selected solely on a pedigree index including one lactation of the dam and the progeny test results of the sire and the MGS with n daughters. The details in the procedures used are presented in page 4.

With the prerequisites chosen heifers as bull dams give a higher DG than alternatives with "conventional" bull dams with information on 1 lactation. As the index by means of which the bull dams are chosen has more information from the sire and the MGS in relative terms the gain in the non yield traits is higher (or the deterioration is lower) when young bull dams are used. It should be stressed that this conclusion is dependent on the prerequisites chosen. Careful performance recording of potential bull dams may give reverse results.

Table 6. Annual genetic gain in DG and in the part indexes with heifers as bull dams at different PYBS-levels with n = 100 compared with "conventional" rather young bull dams as in table 3 and 4.

	PYBS				
n	0.1	0.3	0.4	0.5	0.7
Heifers as bull dams.					
100 DGtotal	1.80	1.97	2.01	2.03	2.03
Prot	1.78	1.95	1.98	2.00	2.00
Dfert	-0.002	0.003	0.005	0.006	0.009
Mast	0.14	0.15	0.16	0.16	0.16
Other	-0.13	-0.13	-0.14	-0.14	-0.13
Conventional bull dams (from tables 3 and 4).					
100 DGtotal	1.76	1.90	1.93	1.94	1.93
Prot	1.76	1.89	1.92	1.93	1.91
Dfert	-0.03	-0.02	-0.02	-0.02	-0.008
Mast	0.12	0.13	0.14	0.14	0.14
Other	-0.14	-0.15	-0.15	-0.14	-0.14

One of the components in the MOET idea is short generation intervals in the DS path. Table 6 shows that the short generation intervals per se do not prevent consideration of the non yield traits. On the contrary, in connection with progeny testing the short generation intervals can even strengthen the position of the non yield traits. The decisive factor is progeny testing or not. If all indexes are based on records on individual cows, no gain can be expected in non yield traits

Summary.

Conventional breeding plans based on selection on an index comprising yield, health and fertility traits give the same general pattern with flat optimum curves as selection plans based on selection for yield. The maximum points at each level of young bull inseminations are found at somewhat lower values of the size of the daughter group when only yield is considered but the differences are small.

The proportion of young bull inseminations has a small effect on the absolute and relative gain in non yield traits. However, the highest PYBS-levels give the highest gains (or the least deteriorations) in non yield traits. The size of the daughter group is by far the most important factor affecting the gains in non yield traits. At a PYBS-level of 0.3 the annual genetic change in the sub-index for Daughter fertility is -0.11 at a daughter group size of 50 but +0.06 when 300 daughters are tested per bull. At the same PYBS-level the annual gain in Mastitis index is 0.05 and 0.25 respectively when n = 50 and 300.

Selection for yield alone is accompanied by a severe deterioration in the non yield traits. If the value of this deterioration is considered selection for yield alone results in a total merit change inferior to the one achieved with a total merit index.

Young bull dams per se does not mean that the gain in non yield traits is retarded. Ih heifers are selected as bull dams by means of a pedigree index including the indexes of the sire and the maternal grandsire the gain in the non yield traits can even be improved in comparison with conventional bull dam selection. However, careful performance recording of potential bull dams in the first lactation may give reverse results.

Cited literature.

Christensen, L.G. 1994. How to make red breeds the most profitable dairy breeds worldwide. The second international Red Cow Club Conference. Sweden, May 1994.

Lindhé, B. 1968. Model Simulation of Al-breeding within a dual purpose breed of cattle. Acta Agr. Scand. 18, 33.

Lindhé, B. 1995. Volvo-Qualität in Skandinaviens Ställen. Der Tierzüchter 4/95, 30.

Lindhé, B. and Philipsson, J. 1995. Effects of unknown vs. known genetic relationships between economically important traits in total merit indexes for dairy bulls. EAAP, Prague.

Pedersen, G.A. and Christensen, L.G. 1993. Optimering av avelsplaner. Sammendrag av indlæg præsenteret ved Kvægavlsseminariet på Forskningscenter Foulum den 9. december 1993. Statens Husdyrbrugsforsøg, Danmark.

Philipsson, J., Banos, G. and Arnason, T. 1994. Present and future uses of selection index methodology in dairy cattle. J. Dairy Sci. 77, 3252.

Rendel, J. M. and Robertson, A. 1950. Estimation of genetic gain in milk yield by selection in a closed herd. J. Genet. 50,1.

Skjervold, H. and Langholz, H.J. 1964. Factors affecting the optimum structure of Al breeding in dairy cattle. Z. Tierzücht. Züchtungsbiol. 80, 25.